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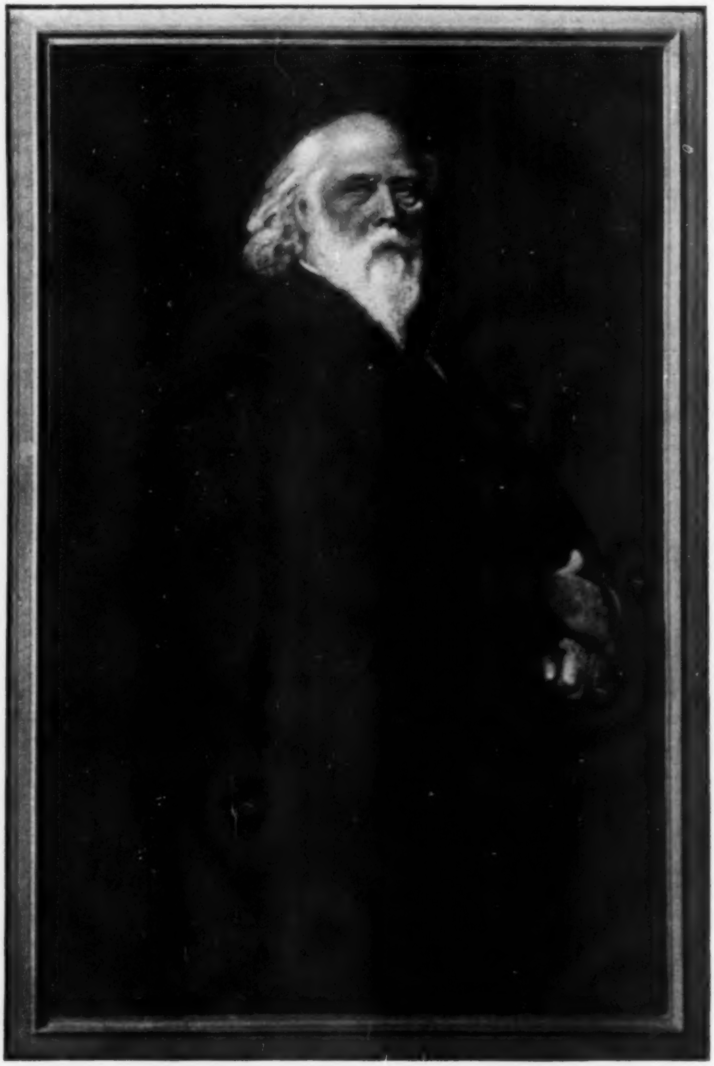

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THE SPECIFIC VOLUME OF SATURATED STEAM

By Prof. C. H. Peabody,[1] Boston, Mass.

Non-Member

For many years the specific volume of saturated steam has been computed from the thermodynamic equation

$$s = \frac{r}{A\,T} \cdot \frac{1}{\frac{dp}{dt}} + \sigma$$

in which the quantities have the following significance:

s is the specific volume, for example the volume in cubic meters of one kilogram.

r is the heat of vaporization in calories.

T is the absolute temperature obtained by adding 273 to the temperature by the centigrade thermometer.

$\frac{dp}{dt}$ is the differential coefficient of the pressure with regard to the temperature, the pressure being in kilograms per square meter.

σ is the specific volume of water (0.01 cubic meters per kg.

2 For this paper French units are used because the original data are given in them and comparison with experimental values is convenient.

3 All the quantities entering into this equation are now determined with a certainty and precision that must be considered satisfactory for engineering purposes and a comparison with experimental determinations of the specific volume shows an exceptionally good concordance.

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To be presented at the Washington Meeting (May 1909) of The American Society of Mechanical Engineers. All papers are subject to revision.

4 To make the exposition of this statement clear it is necessary to review the experimental data and to state the precision that can properly be attributed to them.

5 The mechanical equivalent of heat as determined by Rowland[1] may be taken as 427 meter-kilograms (778 foot pounds) at 15 deg. cent., which corresponds nearly with 62 deg. fahr. There have been more recent investigations which on the whole confirm this result, though there is some indication that it is a trifle small. The uncertainty may be one in a thousand or one in two thousand.

6 Callendar[2] gives for the absolute temperature of freezing point 273.1 deg. cent., with a probable error of one in two thousand.

7 For the range of temperature from 30 deg. to 100 deg. Henning[3] gives the equation

$$v = 94.210\ (365 - t)^{0.31249}$$

in calories at 15 deg. cent. In English units the equation may be written

$$v = 141.124\ (689 - t)^{0.31249}$$

Experiments by Dieterici,[4] Griffiths[5] and A. C. Smith[6] confirm his results and extend the equation to freezing point. The probable error of this equation is one in one thousand.

8 In his paper, The Total Heat of Saturated Steam, read at the Annual Meeting, 1908, Dr. Harvey N. Davis gives for the total heat of steam from 212 deg. to 400 deg. fahr.

$$H = H_{212} + 0.3745\ (t - 212) - 0.000550\ (t - 212)^2$$

Transformed into French units this may be written

$$H = 638.9 + 0.3745\ (t - 100) - 0.00099\ (t - 100)^2$$

provided that the constant term be taken as the sum of Henning's value for r at 100 deg. cent. and the heat of the liquid be taken as 100.2, according to a consideration to be taken up later in this paper. To conform with the conditions already accepted, this equation should give the toal heat in calories at 15 deg. cent., while Dr. Davis used for the calories 1/100 of the heat required to raise one kilogram

[1] Proc. Am. Acad., vol. 15 (n.s. 7), 1879.

[2] Phil. Mag., Jan. 1903.

[3] Annalen der Physik, vol. 21, p. 849, 1906.

[4] Annalen der Physik, vol. 16, p. 912, 1905.

[5] Phil. Trans., 186, p. 261, 1895.

[6] Physical Review, vol. 25, 1907.

of water from freezing to boiling point. The difference amounts to 2/1000, as indicated by the heat of the liquid just mentioned (q = 100.2). Now the total heats at 100 deg. and 200 deg. cent. are 638.9 and 666.5, and their difference is 29.6 calories, so that the total effect is less than one-tenth of a calorie.

9 As for the heat of the liquid we have the three following sources of information:

a Barnes'[1] determinations of the specific heat of water from 0 deg. to 95 deg. cent.

b Dieterici's[2] determinations of the same property from freezing point to very high temperatures.

c Regnault's[3] determinations of the heat of the liquid.

Barnes' experiments were made by an electrical method for which great relative precision is claimed, and they showed a good concordance with Rowland's work on the mechanical equivalent, which in reality was an investigation also of the specific heat. Dieterici's investigation consisted essentially in heating water in a quartz tube, which was then transferred to the ice calorimeter. His results appear to be systematically larger than Barnes'; at 95 deg. cent., the discrepancy is $\frac{4}{10}$ of 1 per cent.

10 In 1907 the author endeavored to join Regnault's values for the heat of the liquid to those deduced from Barnes' values of the specific heat. Now Regnault's experiments consisted in running hot water into a calorimeter partly filled with cold water and noting the rise of temperature in the calorimeter. There were 40 tests in all, scattered irregularly from about 100 deg. to 190 deg. cent. for the temperature of the hot water; there were in a way three groups of tests, one near 110 deg., one near 160 deg., and the third near 190 deg. cent.

11 The average rise of temperature in the calorimeter for the first group was not far from 9 deg. cent., which item appears to account for the considerable irregularity of results at that place. The experiments with the highest temperatures had nearly twice that rise of temperature in the calorimeter and about half the dispersion of results.

12 In order to use Regnault's results his values for the heat of the liquid were recomputed, allowing for the true specific heat of the water in the calorimeter, and then a diagram was plotted as shown

[1] Phys. Review, vol. 15, p. 71, 1902.

[2] Annalen der Physik, vol. 16, p. 593, 1905.

[3] Memoirs de l'Institut de France, vol. 26.

by Fig. 1, in which the abscissae are temperatures and the ordinates are values of $q - t$.

13 This allows of the use of a large vertical scale which much accentuates the apparent scattering of points. A curve was then drawn to join a curve from 0 deg. to 100 deg. cent., from Barnes' results for the specific heat of water. This curve passes near the highest group of points, above the middle group and below the lowest group.

14 It should be said that Barnes' results were first transformed to allow for the use of 62 deg. fahr. for the standard temperature, instead of 20 deg., which he had taken in his report; also that his

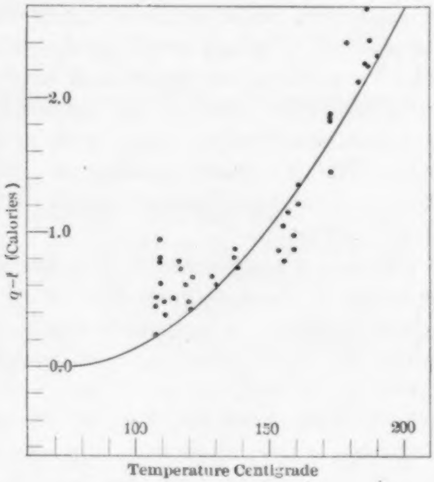

Fig. 1. Recomputation of Regnault's Experiments on the Heat of the Liquid of Water

values were slightly increased at temperatures approaching 100 deg. so as to avoid a break in the curve. The last had the effect of increasing the heat of the liquid at 100 deg. by one one-thousandth.

15 Finally a table of specific heats was drawn off for temperatures from 0 deg. to 220 deg. cent., which served as the basis of a graphical integration for the value of $q - t$. Fig. 2 gives the curve representing the final value of this quantity and also a curve representing values that would be obtained if Dieterici's values for the specific heat were excepted.

16 The author is of the opinion that the full curve in Fig. 2 shows very nearly the true value of the property under consideration, and he has used it to determine heats of the liquid.

17 The maximum deviation of a single point from the curve in Fig. 1 is 0.8 of a calorie, which amounts to $\frac{3}{4}$ of 1 per cent of the heat of the liquid at that point. If we could consider that an error of 0.02 deg. might be attributed to the temperatures in the calorimeter it would account for one-third of that deviation. But to take the most pessimistic view of the situation and charge an error of 0.8 of a calorie against the method, we may still consider that for temperatures above boiling-point the heat of the liquid is always associated with the heat of vaporization, and that their sum is more than

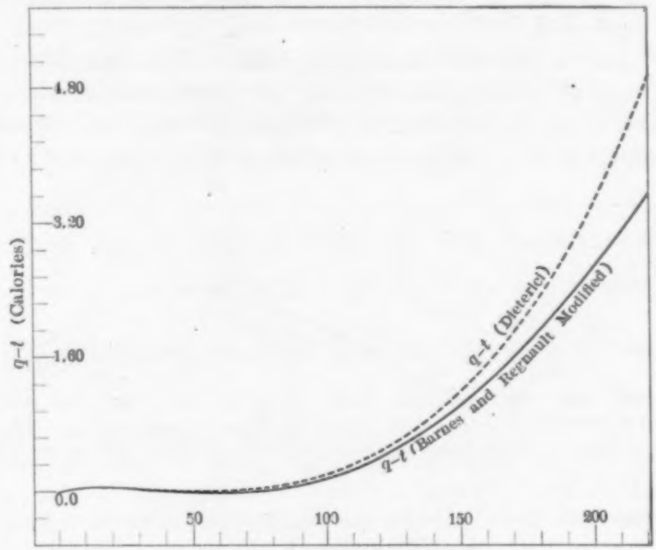

FIG. 2 VALUES OF THE QUANTITY $(q-t)$

THE FULL CURVE SHOWS THE QUANTITY DEDUCED FROM THE AUTHOR'S COMBINATION OF BARNES' EXPERIMENTS ON THE SPECIFIC HEAT OF WATER WITH REGNAULT'S EXPERIMENTS ON THE HEAT OF THE LIQUID, WHILE THE DOTTED CURVE SHOWS RESULTS FROM DIETERICI'S EXPERIMENTS ON THE SPECIFIC HEAT OF WATER.

630 calories, so that the deviation in this light amounts to $\frac{1}{8}$ of 1 per cent.

18 A more just view is clearly to take the deviation of the worst group of points. This occurs at 117 deg. and is about 0.3 of a calorie, that is, 0.25 per cent of the heat of the liquid. The most favorable view is to consider that the upper end of the curve is well fixed by Regnault's experiments, which were then under the most favorable conditions, and that the lower end is tied to Barnes' values, which have all desired precision. This matter is discussed with some detail be-

cause the original experimental results needed to be entirely recast for the present purpose.

19 But while important from some aspects, the quantities with which we are dealing are not affected by uncertainties that concern our main investigation, i.e., the specific volume of saturated steam, for the maximum variation between the author's value for the heat of the liquid, and a value determined from Dieterici's investigation, amounts to 0.8 of a calorie at 200 deg. cent. This is only $\frac{1}{8}$ of 1 per cent of the total heat at that place. However, we need for our specific volume the heat of vaporization, and the discrepancy then becomes $\frac{1}{5}$ of 1 per cent.

20 Recent determinations of the pressure of saturated steam have been made by Holborn and Henning,[1] with all the resources of modern physical methods including the platinum thermometer. They claim a precision of 0.01 deg. in the determination of temperature and that

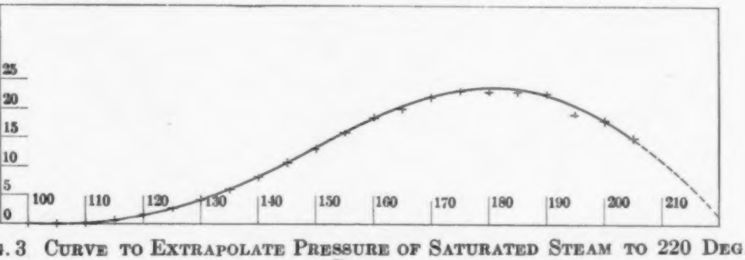

FIG. 3 CURVE TO EXTRAPOLATE PRESSURE OF SATURATED STEAM TO 220 DEG. CENT.

their results reduced to the thermometric scale have a probable error of not more than 0.02 deg. at 200 deg. cent. Their own experiments cover the range of temperature from 50 deg. to 200 deg. cent. (122 deg. to 392 deg. fahr.), and they have extrapolated results to 205 deg. cent. Below 30 deg. they have made use of experiments by Thiesen and Scheel to extend results to freezing points; these experiments were not made with the same degree of precision as those by Holborn and Henning.

21 In order to extend calculations to 220 deg. cent., as has been the habit in computing steam tables, the author made use of a diagram shown by Fig. 3, in which the abscissae are temperatures centi-

[1] Annalen der Physik, vol. 26, p. 383, 1908.

NOTE. Since these results may not be easily accessible, it may be of interest to say that they have been transferred directly to Table 3, of the author's Steam and Entropy Tables, edition of 1909.

grade and the ordinates are differences between Holborn and Henning's value and pressures computed by the following equation:

$$\log p = 5.457570 - 0.4120021\ (9.997411296 - 10)^{t-100} + (7.74168 - 10)\ (9.997411296 - 10)^{t-100}$$

which was chosen as a matter of convenience and because it gave a curve which crossed the axis near 220 deg. cent. when produced. It is thought that the extrapolated values are not much in error, though there is no means of determining this question. Fortunately this part of the range of temperature, as well as that below 30 deg. cent., is not so important to engineers.

22 The degree of precision attained by Holborn and Henning in the determination of the pressure of saturated steam is far beyond any direct technical requirement, since pressures are seldom determined closer than one-tenth of a pound; it is, however, requisite, if the differential coefficient $\frac{dp}{dt}$ is to be determined with certainty and accuracy.

23 Since their results are presented in a table without attempting to represent it by an equation, it becomes necessary to replace $\frac{dp}{dt}$ by $\frac{\Delta p}{\Delta t}$ which can be most readily obtained as follows: for a given temperature, for example 100 deg., we may compute the ratio by taking two adjacent temperatures, such as 98 deg. and 102 deg., finding the difference of pressure, which is to be divided by the difference of temperature; and the result is to be multiplied by 13.5959, because that is the pressure of one millimeter of mercury on one square meter. This result is

$$\frac{\Delta p}{\Delta t} = 13.5959\ \frac{815.9 - 707.3}{4} = 3691$$

24 A number of elements entered into the determination to use this method and to take an interval of 4 deg. If the relation of the pressure to the temperature could be represented by a second-degree curve, that is, if such a curve were a parabola with its axis parallel to the axis of pressure, the ratio $\frac{\Delta p}{\Delta t}$ for any interval would be precisely equal to $\frac{dp}{dt}$. A table of values that could be represented by such a curve would have constant second differences; by second differences are meant the results obtained by taking (*a*) the differences

of successive tabular values, and (*b*) the differences of these differences. An examination of the second differences of Holborn and Henning's values showed great regularity between 50 deg. and 100 deg., i.e., for their own determinations. The second differences increased slowly; for intervals of 4 deg. the increase was imperceptible, for 6-deg. intervals the increase was barely perceptible, but for 10-deg. intervals it was very apparent.

25 Now the possible precision of reading the height of a column of mercury, including allowance for variations of density, is better than the determination of temperature; consequently the probable error to be considered is that attributed to the determination of temperature, namely 0.01 deg., consequently the probable error of a single determination of the ratio $\frac{\Delta p}{\Delta t}$. To diminish the effect of local variations this ratio was computed for each degree of temperature and the regularity of the results thus obtained was tested by taking first and second differences. Where the second differences showed irregularity, the values of the ratio were changed to the extent of 1/1000 in order to improve the regularity of the second differences. This process is equivalent to drawing a smooth or fair curve to represent physical properties obtained by observation.

26 Having values of the ratio $\frac{\Delta p}{\Delta t}$ for each degree of temperature the specific volumes were computed by the thermodynamic equation in Par. 1. They were in turn tested for regularity by taking first and second differences: and again the values were changed when necessary to the extent of 1/1000 to improve the regularity of the second differences. The combined effect of both fairings is estimated not to exceed 1/500 in any case and the author believes that the probable error of the final determinations of the specific volumes is not greater than that amount for the range of 50 deg. to 200 deg. cent.

27 It may further be said that having computed the values of Apu at each fifth degree and plotted the results on a large diagram, no individual values were found to vary from a fair curve more than 1/750.

28 Fortunately there are extant experiments on the specific volume of saturated steam by Knoblauch, Linde and Klebe,[1] made with such a degree of precision as to give a satisfactory check on the computations made by the method described. These experiments

[1] *Mitteilungen uber Forschungsarbeiten*, vol. 21, S. 33, 1905.

consisted in measuring the temperature and pressure of superheated steam at constant volume, and the results were so treated as to give the volume at saturation by a straight-line extrapolation with great certainty. The experimenters give the following equation to represent the properties of both superheated and saturated steam:

$$p\,v = BT - p\,(1+a\,p)\left[C\left(\frac{373^3}{T}\right)-D\right]$$

$B = 47.10$; $a = 0.000002$; $C = 0.031$; $D = 0.0052$, volumes being in cubic meters per kilogram, pressures in kilograms per square meter, and the absolute temperature being on the centigrade scale.

29 For English units the equation may be written

$$p\,u = 85.85\,T - p\,(1+0.00000976\,p)\left[\frac{150{,}300{,}000}{T^3} - 0.0833\right]$$

the volumes being in cubic feet, the pressures in pounds per square foot and the temperatures in degrees fahr.

30 Knoblauch claims for this equation a mean probable error of 1/500, though admitting individual discrepancies of twice that amount. This equation applied to the computation of specific volumes of saturated steam shows a good concordance with results, computed by the thermodynamic equation, the greatest discrepancy being 1/300 at 165 deg. cent. (329 deg. fahr.).

31 Not satisfied with this apparent concordance, which after all was with an empirical equation which on examination showed somewhat larger variation from individual experimental values at saturation, the author had a diagram drawn of the 32 values of the specific volume reported by the experimenters. The diagram was drawn to a very large scale, using temperatures for abscissae and logarithms of volumes for ordinates, and a fair curve was drawn by aid of a stiff spline. From readings on this curve the volumes were determined at 5 deg. intervals, and are set down in the accompanying table together with values computed by the thermodynamic equation.

32 The greatest deviation of values in this table is 0.2 per cent, which is precisely the probable error assigned by the experimenters for their work. It may therefore be concluded that between the limits of temperature in this table and probably from 30 deg. to 200 deg. cent. (86 deg. to 392 deg. fahr.), the probable error of computations by aid of the thermodynamic equation is not in excess of 1/500.

COMPARISON OF EXPERIMENTAL AND COMPUTED VALUES OF THE SPECIFIC VOLUME OF SATURATED STEAM

Temperature	Volume, Cubic Meters			Temperature	Volume, Cubic Meters		
	Experimental	Computed	Per cent deviation		Experimental	Computed	Per cent deviation
100	1.674	1.671	+0.18	145	0.4458	0.4457	+0.02
105	1.421	1.419	+0.14	150	0.3927	0.3921	+0.15
110	1.211	1.209	+0.17	155	0.3466	0.3463	+0.09
115	1.036	1.036	0.	160	0.3069	0.3063	+0.20
120	0.8894	0.8910	−0.18	165	0.2724	0.2729	+0.18
125	0.7688	0.7698	−0.13	170	0.2426	0.2423	+0.12
130	0.6670	0.6677	−0.10	175	0.2168	0.2164	+0.19
135	0.5809	0.5812	−0.05	180	0.1940	0.1941	−0.05
140	0.5080	0.5081	−0.02				

33 This conclusion carries with it the attribution of at least the same degree of precision to all the properties entering into the thermodynamic equation. A little consideration will show that this conclusion covers all the properties given in steam-tables including the entropy. As an apparent exception we have the heat of the liquid at high temperatures which may be uncertain to the extent of $\frac{1}{4}$ of 1 per cent of itself, but as that quantity is then associated with the heat of vaporization the influence of such an error will be of no consequence in computations.

34 It may therefore be expected that steam tables based on the present information will have permanence.

AUTOMATIC FEEDERS FOR HANDLING MATERIAL IN BULK

By C. Kemble Baldwin, Chicago, Ill.
Member of the Society

In the writer's paper on the Belt Conveyor, read before the Society in June, 1908, mention was made of the advisability of using some type of automatic feeder when feeding a conveyor from bulk, for example, from a storage bin. This brief mention of the automatic feeder brought so many inquiries for information regarding feeders for various materials that this paper has been prepared in order to present a brief description of the various types now in use. The cuts are not intended to show the construction, but to illustrate the principle involved, so that they may be compared.

2 Careful study of this subject reveals the fact, so common in engineering, that a particular type of feeder has been developed in a certain industry, or locality, and is little used elsewhere. The types illustrated and described below are only those which have come under the writer's personal observation in many processes and locations within the past fifteen years. There may, therefore, be many other types.

3 When handling dry, free-flowing material such as grain, from a storage bin to a conveyor, a feeder is not required, as a simple gate may be set to give the desired opening, thus allowing the proper quantity to flow from the bin. Should the material be of varying size, such as mine-run coal, a simple gate is not satisfactory unless constantly attended; even then it is impossible to get the same constant, regular feed that a properly designed feeder gives. If the gate is raised high enough to allow a large lump to pass, there usually results a rush of fine material, which floods the conveyor before the gate can be closed. The automatic feeder, therefore, not only saves the expense of an attendant, but insures a constant and regular feed, irrespective of the size of the material.

[1]To be presented at the Washington Meeting (May, 1909) of the American Society of Mechanical Engineers. All papers are subject to revision.

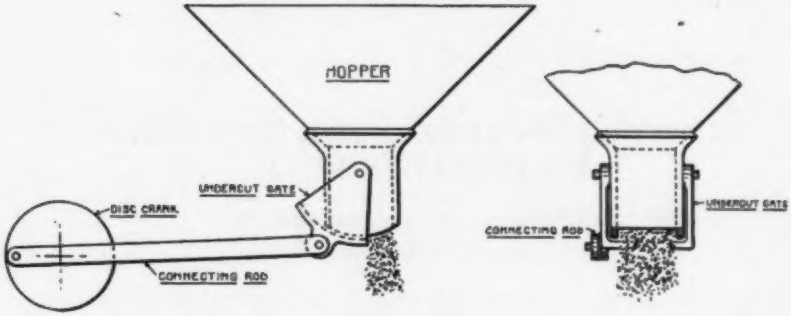

Fig. 1 Undercut-Gate Feeder

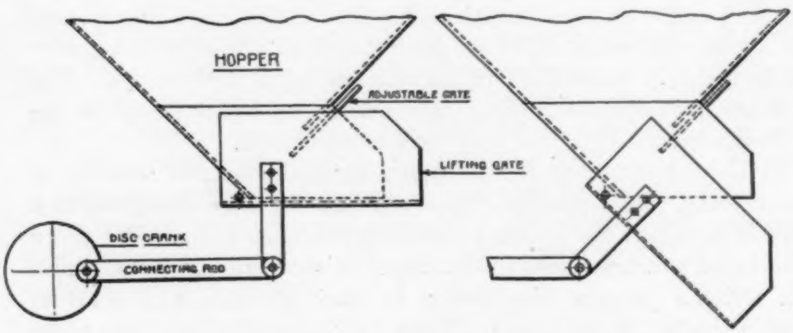

Fig. 2 Lifting-Gate Feeder

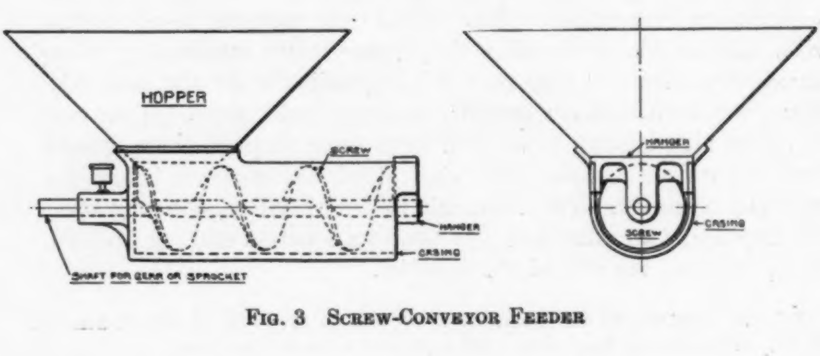

Fig. 3 Screw-Conveyor Feeder

4 Fig. 1 shows the undercut-gate feeder, with a body either of cast-iron or steel plate. Pivoted near the top is the undercut gate—which is swung back and forth by a connecting rod from crank or eccentric. This type of feeder is best adapted to fine-sized, free-flowing material. Material containing lumps is likely to bridge. As the feed is intermittent, the feeder is generally used in connection with chain or bucket conveyors, the strokes being timed to feed material between the flights, or into the buckets. The capacity may be changed only by changing the length or the number of strokes. As the length of stroke is more easily changed, it is preferable to use a crank rather than an eccentric, as in practice the quick return of the eccentric has not been found of sufficient value to offset the great advantage of a crank with an adjustable throw.

5 The lifting-gate feeder, shown in Fig. 2, also gives an intermittent feed and is therefore used only with a chain or bucket conveyor. The chute is hinged, so that when down, the material will flow out of the hopper, but when raised above the angle of flow of the material, the discharge is stopped. The moving of the chute may be accomplished by a connecting rod receiving motion from either crank or eccentric. This feeder will handle material regardless of size, but it must be free-flowing material, so that it will move by gravity when the chute is lowered to the angle of flow. The capacity may be adjusted by varying the number of strokes, also, in a measure, by increasing the length of the stroke, thus increasing the maximum angle of the chute and causing the material to flow more quickly.

6 The screw-conveyor feeder, illustrated in Fig. 3, will deliver a constant stream of material, but in this case also it must be of such a nature that it will flow by gravity to the screw. The capacity can be changed only by altering the speed of the screw shaft. This type of feeder has a large field in the handling of pulverized material, such as coal, cement, etc.

7 The roll feeder, shown in Fig. 4, is extensively used in the mineral industries for handling both large and small materials. The roll is so located under the hopper that the material will not flow when the roll is stationary, but when rotated it will carry the material forward. The capacity is determined by the speed and width of the roll, and the thickness of the stream, as fixed by the adjustable gate.

8 The roll feeder has been successfully used in handling iron-ore, coke and stone from the bins to the weigh cars for furnace changing. Edison used this type for feeding ore and stone from bins to crushing-rolls. The disadvantage is the head-room required, owing to

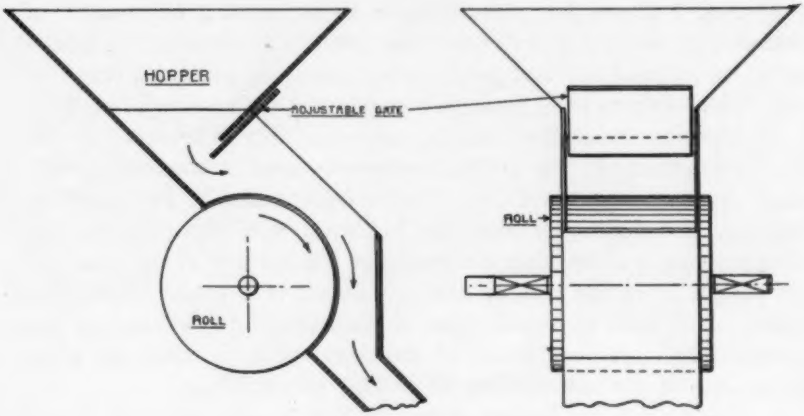

FIG. 4 ROLL FEEDER

the large roll necessary to satisfactory operation. For handling mine-run material, the roll should be 6 ft. to 8 ft. in diameter and in many cases it is not possible to obtain this space.

9 The rotary-paddle feeder, Fig. 5, acts not only as a feeder, but as a measuring device. It is used for fine material which flows readily from the blades. The capacity is fixed by the speed of the paddle shaft.

10 The revolving-plate feeder, shown in Fig. 6, is used mostly for feeding stamp-mills. The inclined plate driven by gears, placed either above (as shown) or below, moves the material out of the hopper

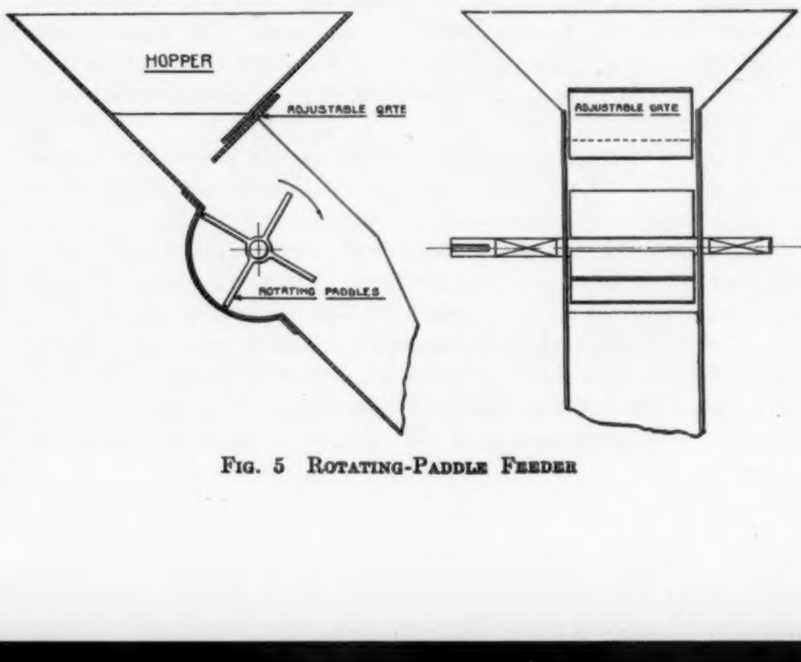

FIG. 5 ROTATING-PADDLE FEEDER

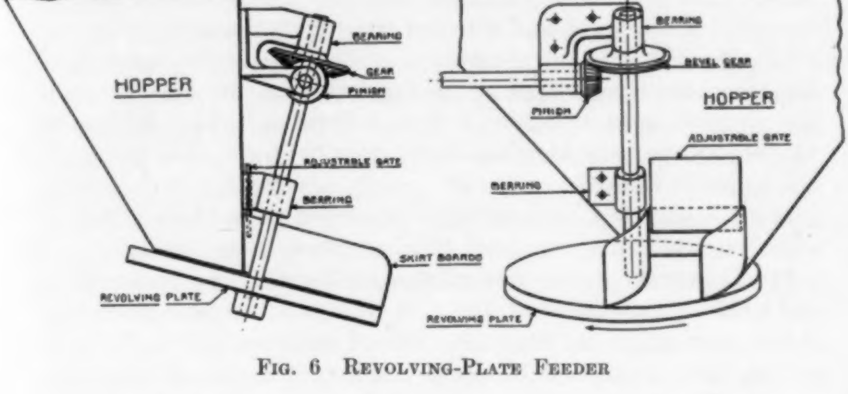

Fig. 6 Revolving-Plate Feeder

where it is scraped off by the skirt-board. When the skirt-board is made adjustable, sticky material may be handled by this feeder because the curved plate will scrape the material off the revolving disc and into the chute. The capacity is fixed by the speed of the plate and the location of the adjustable gate.

11 Fig. 7 illustrates the apron-conveyor feeder used for handling material of all sizes. The conveyor may be of any of the various types of apron flights, depending on the nature of the material handled. The chain should be provided with rollers or wheels traveling on

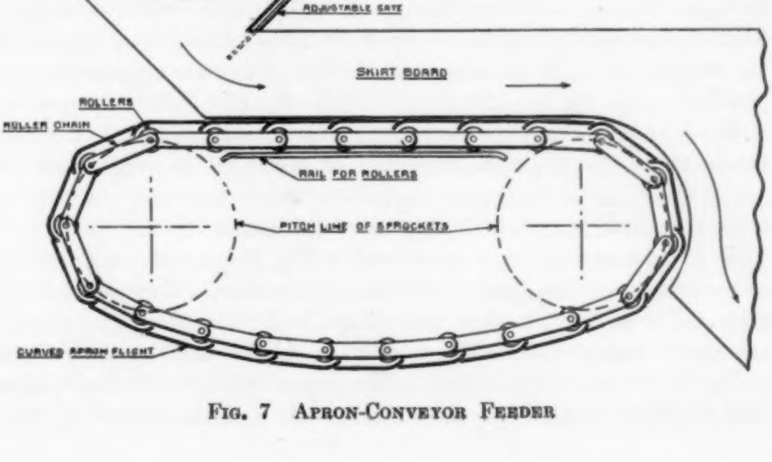

Fig. 7 Apron-Conveyor Feeder

track to prevent the apron from sagging. The capacity is fixed by the speed of the apron and the position of the adjustable gate.

12 The disadvantage of this type is the inherent disadvantage of the apron conveyor. Should the flights become bent or buckled, the material leaks through or catches between them. It has an advantage over other feeders in that it may be used to carry the material a greater distance.

13 A rubber or canvas belt may be used in place of the apron, in which case the belt is supported by idlers placed close together.

14 The swinging-plate feeder, shown in Fig. 8, is used for handling coal and such material of all sizes. It consists of two castings pivoted at their tops and swung alternately so as to move the material forward on the bottom plate. The plates are moved by connecting-rods

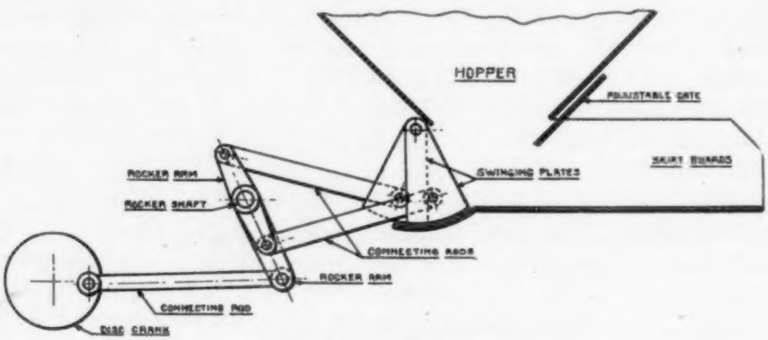

FIG. 8 SWINGING-PLATE FEEDER

from a crank or eccentric through a rocker shaft. The capacity is fixed by the length and the number of strokes, but as it is limited to the amount of material displaced by the plates, a wide range is not possible.

15 The disadvantages are the lack of adjustability and the tendency of the material to pack. It will also be noted that the feeder is not self-cleaning, so that the bottom plate always contains material which is very liable to freeze in winter.

16 The plunger feeder, illustrated in Fig. 9, is similar in operation to the swinging-plate feeder in pushing the material along the bottom plate. The plunger may be built either in one or two parts, moving ahead alternately and driven through a rocker shaft, as in the case of the one previously described. The capacity is fixed by the number and length of the strokes and the location of the adjusting gate.

This type has the same disadvantages as the swinging plate feeder, the most serious being that it is not self-cleaning.

17 Fig. 10 shows the reciprocating-plate feeder, consisting of a plate mounted on four wheels forming the bottom of the hopper. When the plate is moved forward, it carries the material with it, and when it is moved back the plate is withdrawn from under the material, allowing it to fall into the chute. The plate is moved by a connecting rod from crank or eccentric. The capacity is determined by the length and number of strokes and the location of the gate. The disadvantages are the lack of adjustment and the inability to clear the feeder of material.

18 The shaking feeder, Fig. 11, consists of the shaker-pan located under the opening in the bottom of the hopper at such an angle that the material will not flow when the pan is stationary. When given

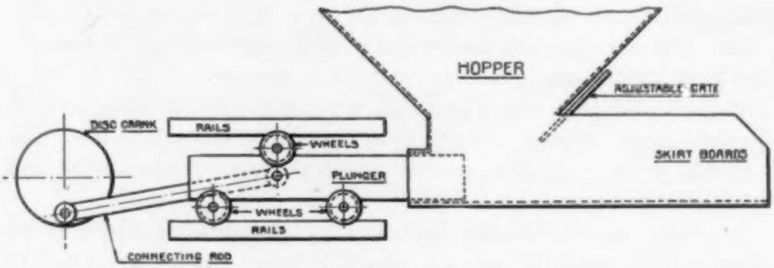

FIG. 9 PLUNGER FEEDER

a reciprocating motion by the crank and connecting-rod, the material is moved forward on the pan. The front end of the pan is carried by a pair of flanged wheels; the back end is suspended by two hanger-rods, each being provided with a turn-buckle so that the angle of the pan may be varied. The crank having an adjustable length of stroke, there are three variables, viz: number of strokes, length of stroke, and inclination of the pan. As the number of strokes is difficult to change, and the others easily changed, the feeders are usually designed for about 75 strokes per min., a number determined by experiment. The angle of the pan is fixed by the capacity desired and the nature of the material handled. For coal, stone, ore, etc., 8 deg. to 10 deg. is sufficient, while clay and other sticky substances require from 15 deg. to 20 deg. The length of stroke varies from 4 in. to 12 in., so that a large range is possible.

19 A feeder designed to handle 400 tons per hr. of mine-run coal

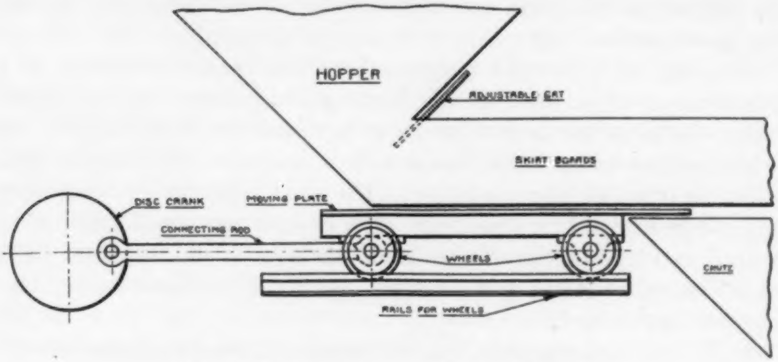

Fig. 10 Reciprocating-Plate Feeder

was changed in five minutes to deliver 30 tons per hr., by shortening the length of stroke and lowering the pan until nearly horizontal.

20 Not only has this feeder the widest possible range in capacity, but it is self-cleaning, a very important feature. From the cut it will be noted that the pan is placed under the opening and the material rests directly on the pan, so that when the pan is moved the material in the hopper is moved, which prevents the material from bridging.

21 The shaking feeder has none of the disadvantages of the other types for general use, and possesses many advantages which the others lack. Owing to its great flexibility it is more easily standardized

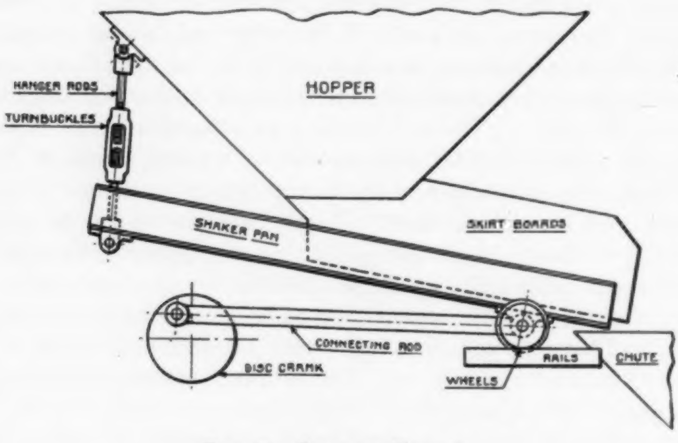

Fig. 11 Shaking Feeder

and will successfully handle practically any material, regardless of size or condition. If desired the bottom plate may be perforated to screen out the fine material thus acting as both screen and feeder. This is not possible with any of the other types.

22 The power required by all of the types is so small that it is not an important consideration. The shaking feeder mentioned above, which handled 400 tons of coal per hr., required but 3.5 h.p.

23 The preceding cuts and descriptions will give a general idea of the different types and their possible uses, so that an engineer may readily choose the best type for the work to be done. The point that should be kept in mind is, that it is always advisable to gear the feeder to the conveyor, crusher, or other machine which it feeds so that they will both start and stop simultaneously.

POLISHING METALS FOR EXAMINATION WITH THE MICROSCOPE

By Albert Kingsbury, Pittsburg, Pa.

Member of the Society

In 1902 the writer made experiments to find the most suitable method of polishing samples of metals for microscopic examination. The polishing of the surface is one of the most important as well as most troublesome details of metallography, particularly when high magnification is required.

2 At the outset, trials were made of all the methods of which descriptions have been published. Some of those methods have been successfully employed by various metallographists, as shown by numerous reproductions of excellent micro-photographs in different publications. Nevertheless the writer did not find any of these free from objectionable features. The ideal method should produce a fairly flat surface, free from excessive relief of the harder constituents, rounded edges at flaws, or scratches and smearing of the metal. The method should be simple, the materials employed readily available, and the process as rapid as consistent with the first-named requisites. None of the published methods embodied all these requisites, nor is a perfect method likely to be found. However, the method finally developed by the writer appears to him superior.

3 The preliminary trials were made with rotating discs covered with various materials, including canvas, felt, silk, leather, chamois, parchment, paper, wood, pitch, asphalt, resin, shellac, beeswax, etc. The polishing powders included commercial abrasives, such as emery, carborundum, tripoli, crocus and jewelers' rouge; also precipitates, such as carbonates and sulphates of the alkaline earths. Attempts were made to obtain fine finishing-powders by the levigation process from commercial abrasives. These abrasives were tried both wet and dry and with various speeds of the discs. Hand polishing was also tried.

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It is needless to detail the objectionable features encountered, which are probably familiar to all metallographists.

4 The method finally adopted was the result of two distinct discoveries: (*a*), that ordinary paraffin wax makes a good polishing bed; (*b*), that excellent polishing-powders of certain grades are commercially available.

5 The paraffin is used as a facing for rotating discs of metal, preferably brass, about 8 in. in diameter. The discs are grooved on the flat face for anchoring the wax. To prepare the discs, they are warmed to about 100 deg. cent., and laid flat, and the melted paraffin is poured on them to a depth of about ½ in., a removable ring or band retaining the melted wax. The whole is then covered to exclude dust and allowed to cool. After the wax has solidified it may be dipped in water to hasten the hardening. Since the wax has very little viscosity when melted, all hard foreign particles, which might produce scratches in the samples, settle out before the wax hardens, the elimination being practically complete. No advantage in this respect was gained by keeping the wax in a fluid condition on the disc for several hours in an oven. After the hardening of the wax, the discs are placed on the spindle of the polishing machine and the face of the wax is turned true and flat by a hand-tool.

6 In the writer's machine the spindle was horizontal and four discs were used, for abrasives of progressive fineness, two discs being placed back to back at each end of the spindle. The disc used for the final polishing should not be perforated and the wax should be continuous to the center of the disc, as that part is best for the finishing touches to the sample. This latter disc should be at the right-hand end of the spindle. The speed of rotation should be about 200 r.p.m.; a higher speed throws off the polishing-powder with the water used, and a lower speed makes the work too slow. A stationary sheet-metal strip about 3 in. wide bent over the discs serves as a screen.

7 The polishing-powders, in the order used, were as follows: (*a*) commercial flour of emery; (*b*) washed Naxos emery, 3/0 grade; (*c*) washed Naxos emery, 7/0 grade; (*d*) soft optical rouge, light grade. these were obtained from the George Zucker Co., New York, except the first, which is available everywhere.

8 The emery powders were mixed to a paste with water in tall glass jars provided with covers; the paste was applied to the rotating discs with small brushes as required, the brushes being kept in the jars when not in use. The rouge was in cake form, best applied by holding a small piece in the hand, wetting both the rouge and the wax, and pressing the rouge lightly against the rotating surface.

9 A small quantity of water is required throughout the polishing process, but water cannot be used very freely without wasting the powders. The water is best applied as required, from an ordinary chemist's wash-bottle, held in the left hand while the right hand manipulates the sample. No water-pipes or drains are required for the polishing machine. Distilled water may be used if available. If tap-water is used, it should be drawn into large jars provided with covers and siphons, and allowed to stand a day or more before use, in order that all gritty particles in suspension may be deposited. The inner ends of the siphon tubes should be at least 3 in. above the bottom of the jars.

10 The treatment of the samples is as follows: the samples are first dressed to shape and size by any convenient method, the surface to be polished made flat by an emery wheel or file, and the sharp edges rounded to prevent cutting into the wax. The dimensions of the samples should depend to some extent upon the coarseness of structure. For normal iron and steels, and for much other work, a $\frac{3}{8}$-in. cube is a convenient sample. Massive castings sometimes have grains an inch or more in diameter, and correspondingly large samples are required. The samples are held flat against the waxed discs, which are kept well covered by the polishing-paste, using successively the flour of emery, the 3/0 emery, the 7/0 emery, and the rouge, on the several discs. At each grinding with emery the sample should be held without rotation and with a slow transverse motion across the face of the disc until the grinding marks show over the entire surface. The sample may then be given a quarter turn, so that the new marks cross the old ones, and so on. The discs must be kept wet continually while grinding. With each grade of powder the grinding should continue for some time after the marks of the last previous grade have disappeared, especially with soft metals, since the scratches cause a flow or disturbance of the metal to a minute depth below the surface, and if this disturbed metal is not ground off, the deep effect of the scratches becomes apparent on etching. In the final polishing on the rouge disc, the sample should be continuously rotated; this is most readily done by moving the sample nearly in a circle about the center of the disc in an opposite direction from the rotation of the disc. This keeps the direction of the grinding marks constantly changing, and avoids grooving. The finishing should be done near the center of the disc, the slower motion being most effective for very fine polishing. After grinding with one grade of powder and before proceeding to the next, the samples and the operator's hands should be thor-

oughly washed; and the hands and the apparatus should be kept free of dust or dirt, to secure a polish free from scratches.

11 The most important item to be noted by the beginner is the liability of the paraffin to adhere to the samples when the grinding is begun, particularly in the case of the rouge disc. When the sample is first brought into contact with the disc, especially if the latter has been freshly prepared, the paraffin nearly always smears over the surface of the sample in a second or two, and if the sample is not removed and cleaned at once the result is a roughened disc, requiring re-turning with the hand-tool and re-application of the paste. Therefore the sample should at first be touched very lightly to the disc, and at once removed and wiped with the finger, or with a cloth. If this is repeated several times, the surface of the sample will no longer become coated with paraffin but can be ground continuously, except when a fresh coating of paste is required by the disc. One great advantage of the paraffin disc over discs covered with cloth or felt, is that if the disc becomes roughened or cut, it can readily be turned smooth and true again.

12 For cleaning the samples after polishing, the best material is a stock of old linen or cotton cloth well-laundered and cut to 3-in. squares. These small pieces are preferable to larger ones, since they can be discarded for fresh ones after once using. The old cotton or linen is also the best material for cleaning the lenses and mirrors of the optical apparatus, being superior to chamois for this purpose.

13 The time required for polishing a sample varies somewhat with the hardness. A single sample of normal steel, cast-iron, or wrought-iron, may be finished in fifteen minutes; a set of five or six such samples may be finished in an hour. Hardened steels require a slightly longer time. The method has not thus far proved serviceable for very soft metals and alloys, particularly lead, owing to the persistent adhesion of the paraffin to the surface of the sample. The harder alloys polish well by this process. The finished surface presents a minute relief of the harder constituents, but much less than is produced by the use of felt or other very soft materials.

14 The paraffin beds are more durable than might be supposed; on long standing at summer temperatures the surfaces become distorted by the flow of the wax, but they can always readily be made true by the turning tool. The harder paraffin (ceresin) offers no advantages over ordinary paraffin, except that it flows less at summer temperatures. It is serviceable for use with the emery powders but too hard for best results with the rouge.

A NEW TRANSMISSION DYNAMOMETER

By Prof. Wm. H. Kenerson, Providence, R. I.
Member of the Society

The author has received from time to time many requests for a simple transmission dynamometer, and has himself often felt the need of one which would be more generally applicable than those now in use. These continued requests, together with the requirements of a definite problem whose solution demanded a rigid transmission dynamometer in the form of a coupling, led to the design and construction of the instrument described below. The accompanying illustrations show the construction of the dynamometer and its method of application and use. In Fig. 2 and Fig. 4 the corresponding parts of the dynamometer are given the same letters and are referred to in the text.

2 The couplings *A* and *B*, each keyed to its respective shaft, are held together loosely by the stud bolts *C*. The holes in the flange *A* are larger than the studs *C*, so that these studs have no part in transmitting power from one shaft to the other. The power is transmitted from *A* to *B* through the agency of the latches *L*, four of which are arranged around the circumference of the flange *B*. These latches are mounted and are free to turn on the studs *E*. The two fingers of the latches engage the studs *F* on the flange *A*. On the ends of each latch are knife-edges parallel to the stud about which the latch turns. For either direction of rotation of the flange *A* the latches *L*, which are in effect double bell-crank levers, will exert a pressure on the disc *G*, tending to force it axially along the hub of the coupling *B*, and this pressure, it will be seen, is proportional to the torque.

3 Between the end-thrust ball, or roller, bearings *M M*, is held the stationary ring *S*, which is the weighing member. *O* is a thrust-collar screwed on the hub of *B*, and *P* is its check nut, which is ordinarily pinned to the hub when in position. The stationary member

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S, in the form of a ring surrounding the shaft, is prevented from rotating by fastening to some fixed object the attached arm shown in the view (Fig. 1) of the assembled instrument. In this ring is an annular cavity covered by a thin, flexible copper diaphragm *D*, against which the ball-race of one of the thrust-bearings presses. The edge of this ball-race is slightly chamfered to allow some motion

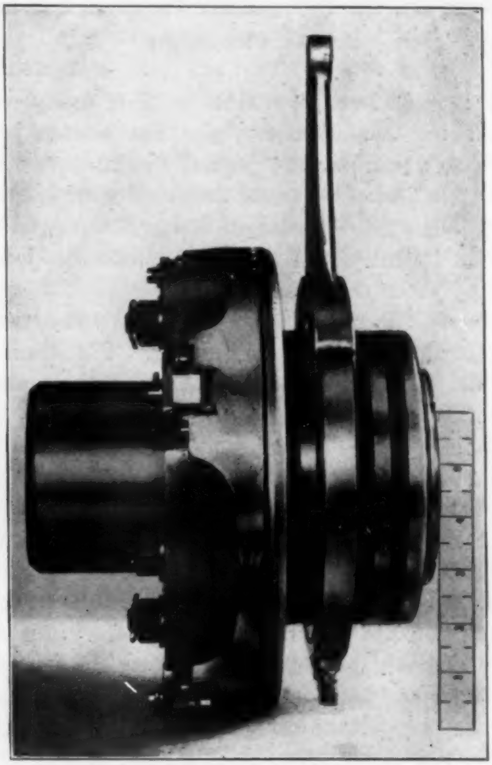

FIG. 1 DYNAMOMETER FOR 2-IN. SHAFT, WEIGHT 60 LB.

to the diaphragm. The cavity is filled with a fluid, such as oil, and connected by means of a tube to a gage. The oil pressure measured by the gage is proportional to the pressure between the thrust-bearings, which in turn is proportional to the torque.

4 The instrument may be calibrated in the torsion-testing machine or by means of a sensitive friction brake. Fig. 6 is an actual calibration curve for a small instrument, obtained by hanging standard

weights at proper distances from the shaft on a horizontal lever attached to the shaft, and reading the pressures indicated by the gage for the various torques shown in the diagram. For ordinary purposes, however, it is not necessary to calibrate the instrument by actual trial, since computations of the oil pressures for the various torques from the lengths of the lever-arms and diaphragm area check very closely those thus obtained.

5 It will be seen that the weighing means is similar to that employed in the Emery testing-machine, which is recognized as being extremely accurate. It will be possible to employ the Emery flexible

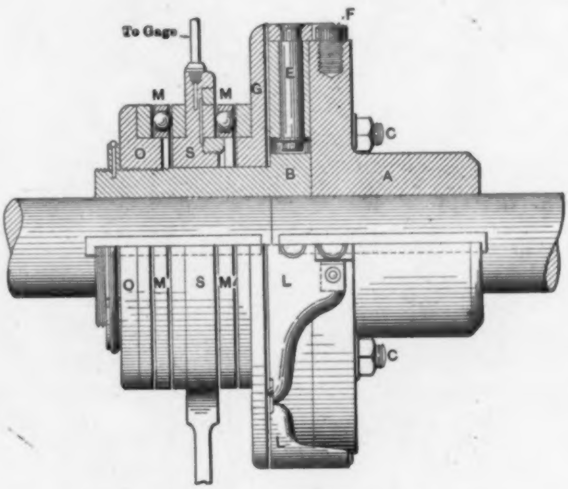

Fig. 2 Dynamometer Shown in Section

steel knife-edges on the levers, if desired, but this has been found in practice an unnecessary refinement.

6 The construction makes the coupling as nearly rigid as materials will permit, the movement of the diaphragm being extremely small. The only flow of oil through the copper connecting-pipe is that sufficient to alter the shape of the Bourdon tube, if that be the form of gage employed. As soon as the normal position of the gage is reached this flow ceases, hence there can be no fluid friction. It is possible therefore, to use as long and as small a tube as desired, without introducing error. Where the gage is placed at a distance above or below the coupling, correction should of course be made for the static head.

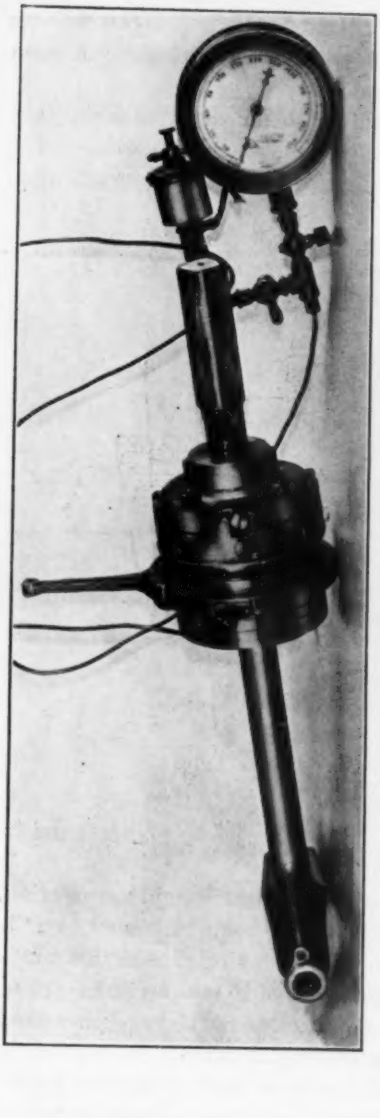

FIG. 3 TRANSMISSION DYNAMOMETER IN AUTOMOBILE PROPELLER SHAFT, 30 H.P. AT 500 R.P.M., WEIGHT 25 LB.

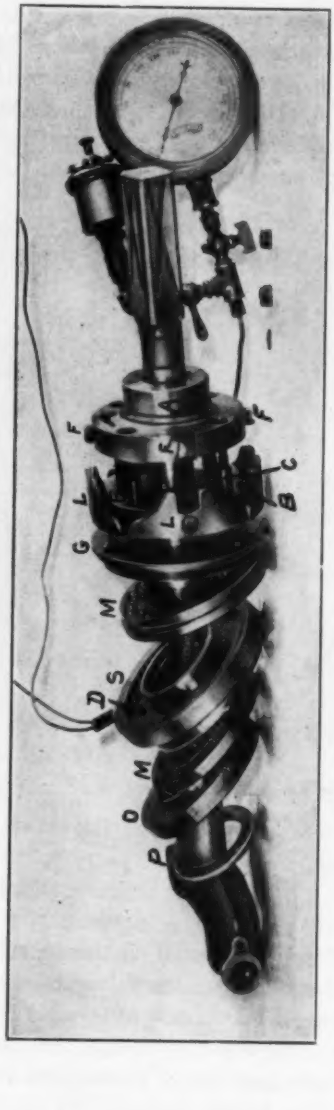

FIG. 4 TRANSMISSION DYNAMOMETER TAKEN APART TO SHOW CONSTRUCTION

7 Other means than the gage shown may be employed to measure the fluid pressure. Where extreme accuracy is desired it will be well to employ the weighing-device used with the Emery testing-machine. The manograph has been used in this connection to measure variations in torque too rapid for indication by the ordinary gage. For example, the variations in torque in a single revolution of the shaft of a 3-cylinder gasolene engine have been recorded with its aid.

8 Where the rate of rotation of the shaft is variable and it is

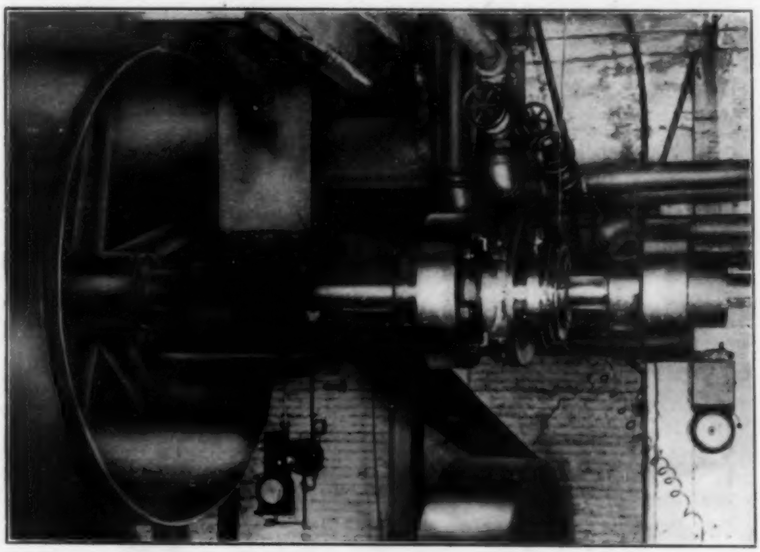

FIG. 5 DYNAMOMETER PLACED BETWEEN FLANGES IN MACHINE-SHOP DRIVE

SHAFT 3 IN. IN DIAMETER. SPIRAL RUNNING TO THE WALL IS OIL-PIPE TO GAGE

desired to indicate the horsepower direct, the combination of gage and tachometer shown in Fig. 7 is employed. The hydraulic gage is connected to the coupling described, its pointer therefore indicating torque. The pointer of the tachometer shows the number of revolutions per minute. Being a function of the revolutions per minute and the torque, the horsepower will be indicated by the intersection of the two pointers and suitable curves on the dial as shown. Arrangements for recording or integrating the work done may also be attached to the coupling.

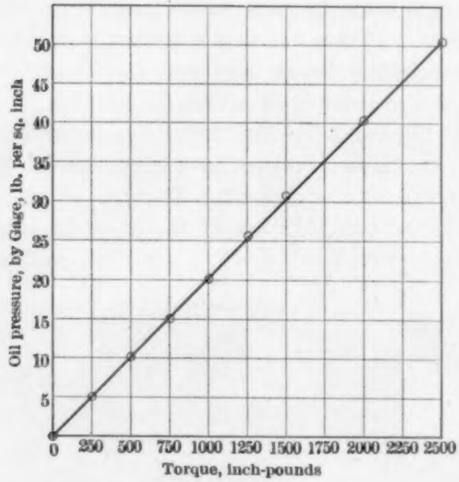

Fig. 6 Calibration Curve for Transmission Dynamometer

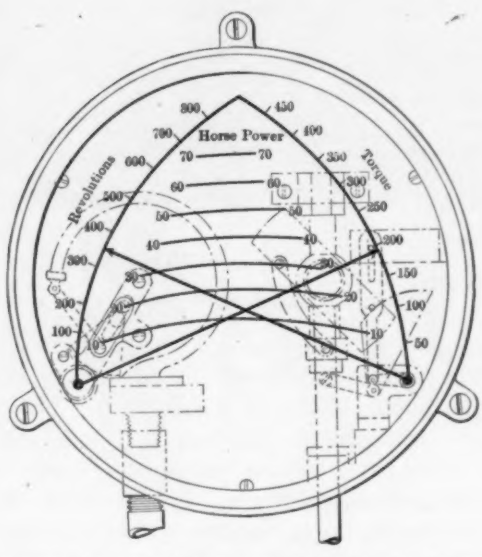

Fig. 7 Combination Pressure-Gage and Tachometer Indicating Torque, Revolutions per Minute and Horse Power

9 A summary of some of the more important characteristics of the instrument follows:

a The instrument is compact. The example shown in Fig. 3 and Fig. 4, which is designed to transmit 30 h.p. at 500 r.p.m., is about $5\frac{3}{8}$ in. in diameter and weighs about 25 lb. That shown in Fig. 5 driving a 3-in. shaft is about 13 in. in diameter and weighs about 160 lb.

b It is as rigid as an ordinary flange coupling.

c It may be made in the form of a coupling, and will then occupy about the same space as the usual flange coupling, or it may be made in the form of a quill on which a pulley is mounted. This form may be made in halves for application to a continuous shaft.

d It will indicate for either direction of rotation of the shaft.

e The torque may be read and recorded or the work integrated at a considerable distance from the coupling.

f The readings do not require correction for different speeds of rotation. All parts containing oil are stationary, hence are unaffected by variation in speed. Other parts are likewise unaffected by centrifugal action.

g It may be made very sensitive and accurate. The construction lends itself very easily to variation of range of application and to varying degrees of sensitiveness, since the oil pressure, and hence the sensitiveness of the instrument, depend upon the area of the diaphragm, the relative lengths of the arms of the latches L, and the diameter of flanges. Its accuracy is dependent mainly on the degree of accuracy of the means employed to measure the fluid pressure, of which a number of forms, other than the usual pressure-gage, are available.

h The only power absorbed is the small amount due to the friction of the ball, or roller, bearings, and this can be determined from the pull of the retaining arm. It is unnecessary to make correction for this, however, since the amount is so small as to be negligible.

i Since the only wearing parts are the ball, or roller, bearings, which may be lightly loaded, the instrument should not be deranged easily. Because of the very small volume of oil contained in the weighing chamber, ordinary temperature changes do not affect the calibration. All parts containing oil are stationary, hence all joints may be soldered and leakage entirely prevented.

j With suitable material and ordinary workmanship, it is believed that there is little likelihood of failure of any part of the instrument. It is conceivable, however, that the balls or rollers, although lightly loaded, might crush; the diaphragm might shear; or the stationary member, although bearing only its own weight and lubricated, might seize to the hub. Remote as are any of these possibilities, should any or all of them occur, the worst that could happen would be the tearing-off of the oil pipe and retaining arm, when the whole would revolve as a solid coupling. In no case can the coupling fail to drive the shaft because of its variation from the standard form, since, in addition to the driving-latches employed to carry the load normally, the same number of connecting bolts may be employed as in the ordinary coupling, which will still hold the coupling together should the latches fail. Since, however, these latches are farther from the shaft, they should, if properly constructed, be less likely to fail than the connecting bolts usually employed.

10 It is believed that uses for the instrument here described will suggest themselves, and it is with the hope that the device will prove of some interest to those who deal with the use and transmission of power that the matter is presented to the Society.

SMALL STEAM TURBINES

By George A. Orrok, New York

Member of the Society

The papers upon steam turbines which have been presented before the Society have dealt mainly with the larger types of apparatus and have been written to show the reliability, efficiency and general desirability of this type of prime mover.

2 This paper treats of the smaller sizes of steam turbines from the standpoint of the designing and operating engineer, describing the commercial machines in sufficient detail, with reference to the service to which they have been applied, and giving certain facts concerning their operation which may be of advantage to the engineering profession. Curves of steam consumption are given which show in a general way what may be expected of these machines under certain conditions.

3 At the present time seven machines are on the market and can be obtained in various sizes from 10 h.p. to 300 h.p. with reasonable deliveries. These are the De Laval, Terry, Sturtevant, Bliss, Dake, Curtis and Kerr turbines. Three other machines are nearly at this stage of development and patents have been applied for on several others.

4 Many thousand horsepower of these turbines have been sold and are in successful commercial service. The following reports of total sales of sizes from 10 h.p. to 300 h.p. have been obtained from the manufacturers:

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For further discussion of Steam Turbines, consult Transactions as follows: Vol. 10, p. 680, Notes on Steam Turbines, J. B. Webb; vol. 17, p. 81, Steam Turbines, W. F. M. Goss; vol. 22, p. 170, Steam Turbines, R. H. Thurston; vol. 24, p. 999, Steam Turbines from the Operating Standpoint, F. A. Waldron; vol. 25, p. 1056, The De Laval Steam Turbine, E. S. Lea and E. Meden; vol. 25, p. 1041, The Steam Turbine in Modern Engineering, W. L. R. Emmet; vol. 25, p. 782, Different Applications of Steam Turbines, A. Rateau; vol. 25., p. 716, Some Theoretical and Practical Considerations in Steam Turbine Work, Francis Hodgkinson.

De Laval,	De Laval Steam Turbine Company................	70,000 h.p.
Curtis,	General Electric Company......................	70,000 h.p.
Terry,	Terry Steam Turbine Company..................	15,000 h.p.
Kerr,	Kerr Turbine Company........................	10,000 h.p.
Sturtevant,	B. F. Sturtevant Company....................	
Bliss,	E. W. Bliss Company..........................	
Dake,	Dake-American Steam Turbine Co..............	

5 All of these machines are of the impulse type: that is to say, the steam is expanded in a nozzle and the kinetic energy of the jet is absorbed by passing one or more times through the buckets of the

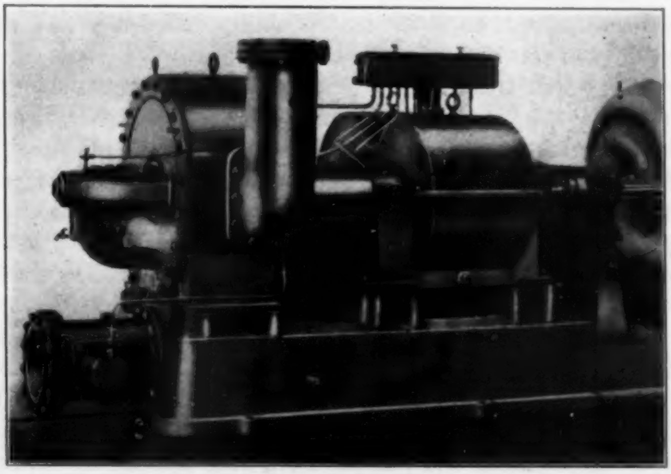

Fig. 1 High and Low-pressure De Laval Turbine

turbine rotor. In the De Laval turbine only one moving element and one steam pass are used, which necessitates a very high bucket velocity. In the Terry, Sturtevant, Bliss and Dake turbines a series of return passages is provided. The steam returns two or more times to the same rotor and the bucket speed is much lower. In the Kerr turbine the steam is used in stages with one bucket wheel in a stage; while in most of the Curtis machines two or three stages are used with two or three rows of moving buckets, separated by stationary guide blades, in each stage. Compound machines of the other types have been made but are not as yet produced commercially.

6 By far the larger number of these machines is used in connection with extra high-speed electric generators, the next larger application

being to centrifugal fans for high pressures. Centrifugal pumps adapted to high rotative speeds have been rather generally introduced in the last few years and it is becoming usual to connect small turbines direct to these machines. The small space required and the simplicity obtainable in a 100-h.p. turbine at speeds of from 800 to 1200 r.p.m. has been an important factor in their introduction.

7 The first of the small turbines to be put on the market was the De Laval, made by the De Laval Steam Turbine Company of Trenton, N. J., and introduced in this country about 1896. This machine is of the

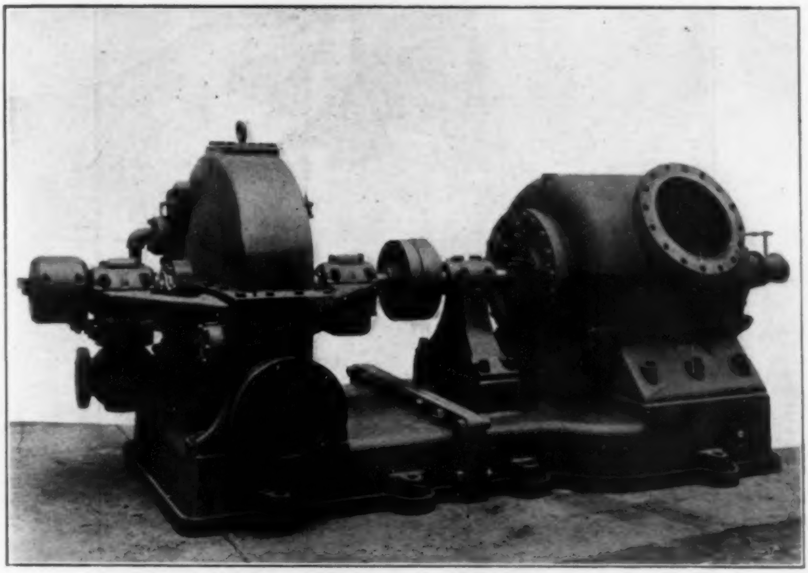

Fig. 2 Terry Steam Turbine, 36-in.

pure impulse type; the steam being expanded in the nozzle down to the exhaust pressure, and the resultant velocity transferred to the wheel in one steam pass. The bucket speed is high, ranging from 600 to 1300 ft. per sec. Eight sizes of wheels are made, generating from 10 h.p. to 500 h.p., with one nozzle in the smallest size and eight or more in the 500-h.p. size.

8 The high bucket speed necessitates the use of gears of special construction, which have been very successful. The design, construction, and economy of this type have been discussed in Vol. 25 of Transactions, p. 1056.

9 The Terry Turbine, made by the Terry Steam Turbine Company of Hartford, Conn., has been manufactured for about ten years, although the commercial machine has been on the market only for about four years. This turbine is of the impulse type, but the steam passes through the buckets a number of times before its energy is absorbed. The case of the machine is parted on a horizontal plane through the shaft and at right angles to the wheel. The nozzles and

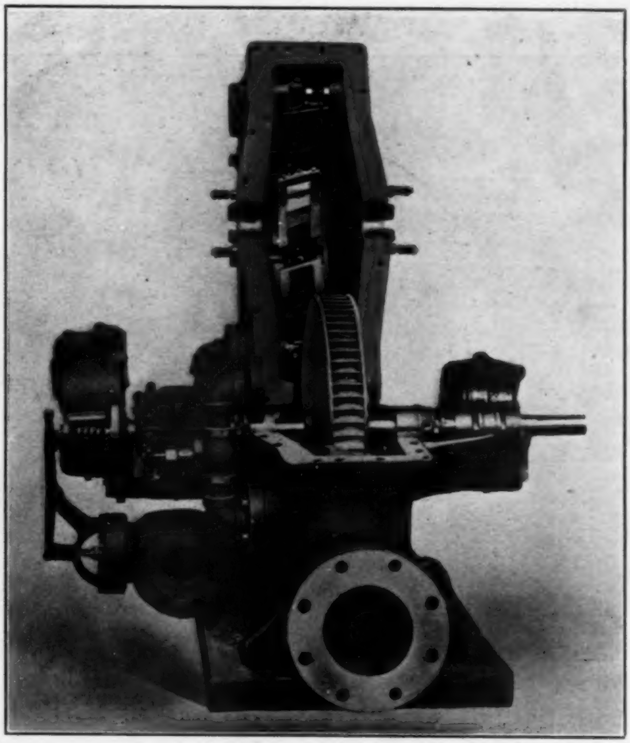

FIG. 3 TERRY TURBINE SHOWING CONSTRUCTION

return passes are bolted to the inside of both parts of the casing. The nozzles are in the plane of the side of the wheel. The return passages are of brass and are separated by partitions. The wheel itself is built up of two steel discs held together by bolts over a steel center. The buckets are built of steel punchings, fitting in grooves cut in the discs, as shown by the figures. The sizes of wheels manu-

factured at the present time are 12, 18, 24, 36 and 48 in., and the number of nozzles varies from two on the 12-in. wheel to eight or ten no the 48-in. wheel.

10 The Sturtevant Turbine, made by tbe B. F. Sturtevant Company of Hyde Park, Mass., has been in the development stage for three or four years and quite a number of machines have been sold. The present type of turbine may be called "standard," however, and four sizes of wheel are built, 20, 25, 30 and 36-in., developing from

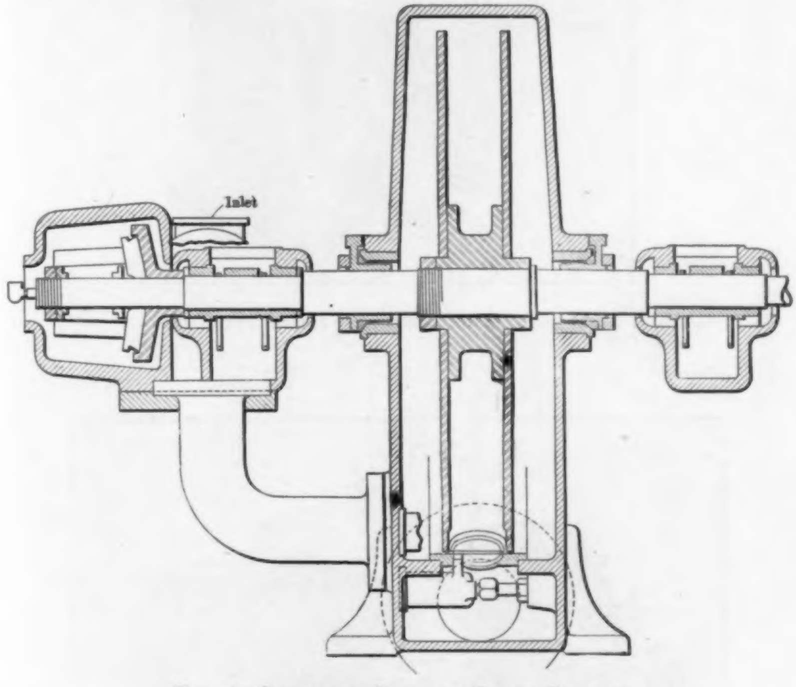

FIG. 4 SECTIONAL VIEW OF TERRY TURBINE

3 h.p. to 300 h.p. The turbine is of the multiple-pass type similar to the Riedler-Stumpf. The casing is cast solid with one end. The nozzle and return chamber ring are inserted from one side and the wheel is milled from the solid. The return passages are from eight to twelve in number and are milled on the inside of the return chamber ring. They are partitioned and are similar in shape to the buckets. The nozzle lies in the plane of the side of the wheel.

11 The Bliss turbine, formerly known as the American, made by the E. W. Bliss Company of Brooklyn, N. Y., is of the same type as

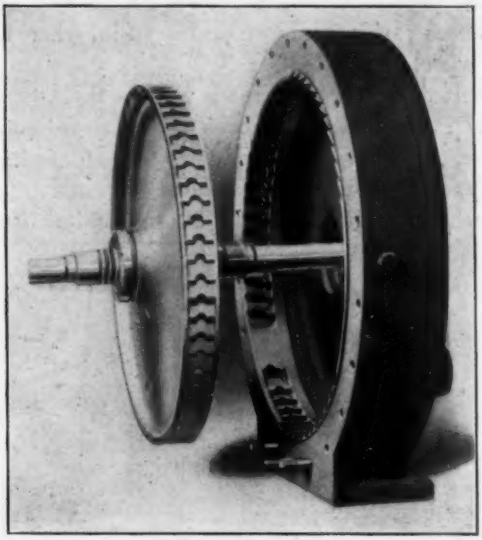

FIG. 5 WHEEL AND CASING OF STURTEVANT TURBINE

FIG. 6 STURTEVANT STEAM TURBINE, 30-IN.

the Terry and Sturtevant and has been on the market only a few months. The casing and steam chamber are cast solid with one side and the nozzle and return chambers bolted in. The wheel is milled from a steel casting, or forging in the smaller sizes, and the partitions

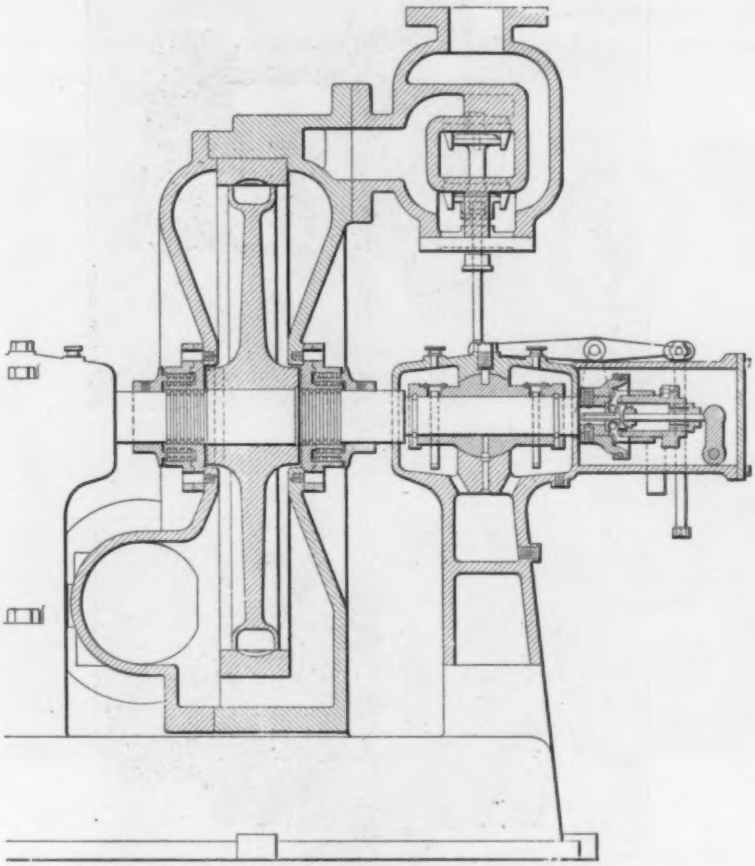

FIG. 7 SECTION OF STURTEVANT TURBINE

separating the buckets are inserted and held in place by three bands of steel shrunk on the face of the wheel. The return passages are peculiar in having no partitions. Two sizes of wheel have been built, the 42-in. and 30-in., but designs have been developed for the 12, 18, 24, 36, 48 and 60-in., covering powers from 10 h.p. to above 600 h.p.

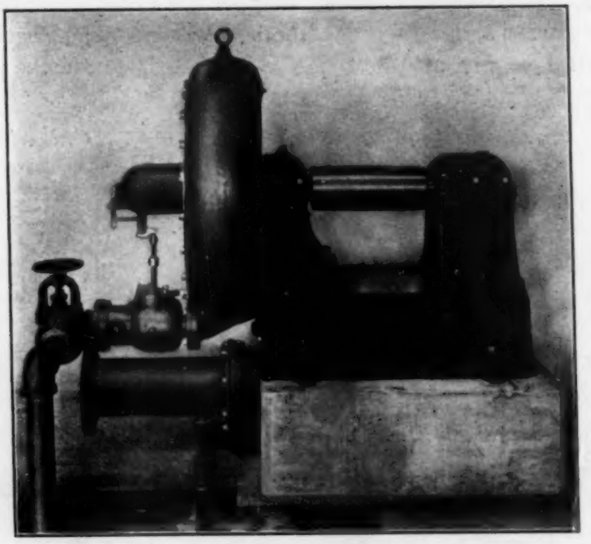

Fig. 8 Bliss Turbine, 30-in.

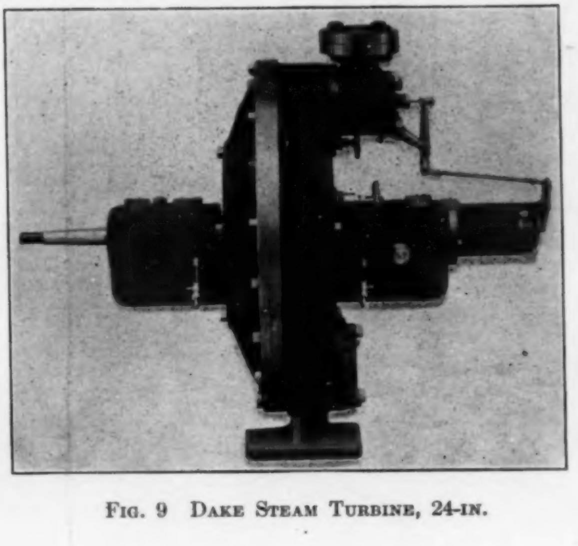

Fig. 9 Dake Steam Turbine, 24-in.

12 The Dake turbine, made by the Dake-American Steam Turbine Company of Grand Rapids, Mich., is a single-stage impulse turbine. The wheel is made of two bucket discs, with milled buckets and inserted partitions, bolted together over a wheel center. In their Headlight turbine the governor is enclosed between the sides of the wheel. The nozzles and return-passages are placed between the bucket discs. The machine is built in sizes of from 5 h.p. to 100 h.p., the diameter of the smallest wheel being 12 in.

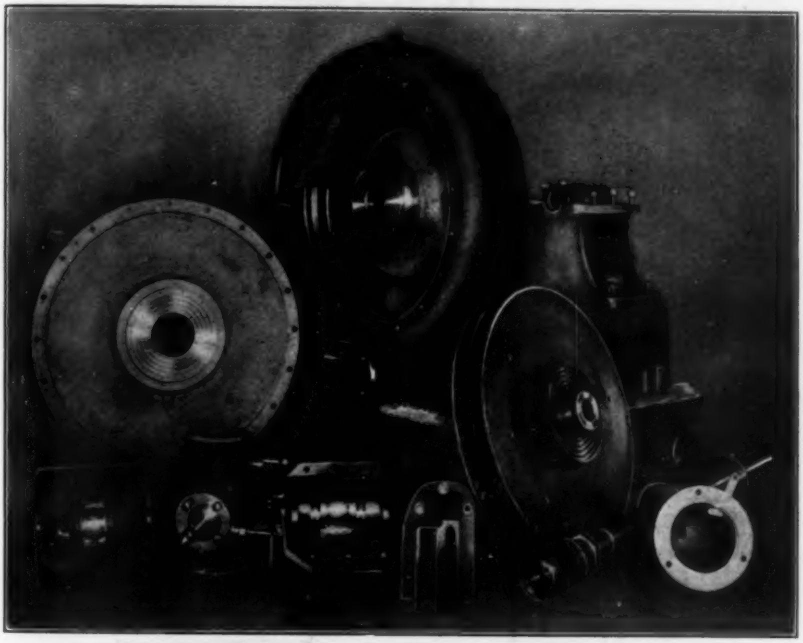

FIG. 10 BLISS TURBINE DISSEMBLED

13 Coincident with the development of the large Curtis turbines, the General Electric Company, at their Lynn Works, have developed and placed on the market a line of small generating sets ranging from 5 kw. to 300 kw. This range is covered by eight sizes, the smaller machines being single-stage with two or three passes per stage. The buckets and nozzles are of the well-known Curtis type.

14 The Kerr Turbine, made by the Kerr Turbine Company of Wellsville, N. Y., is of the compound impulse type. It is generally built in from two to eight stages. The buckets are of the double

Pelton type, inserted like saw teeth in the wheel disc. Four sizes of wheels, 12, 18, 24 and 36 in., are made and cover a range of from 10 h.p. to 300 h.p. The nozzles are in the plane of revolution of the

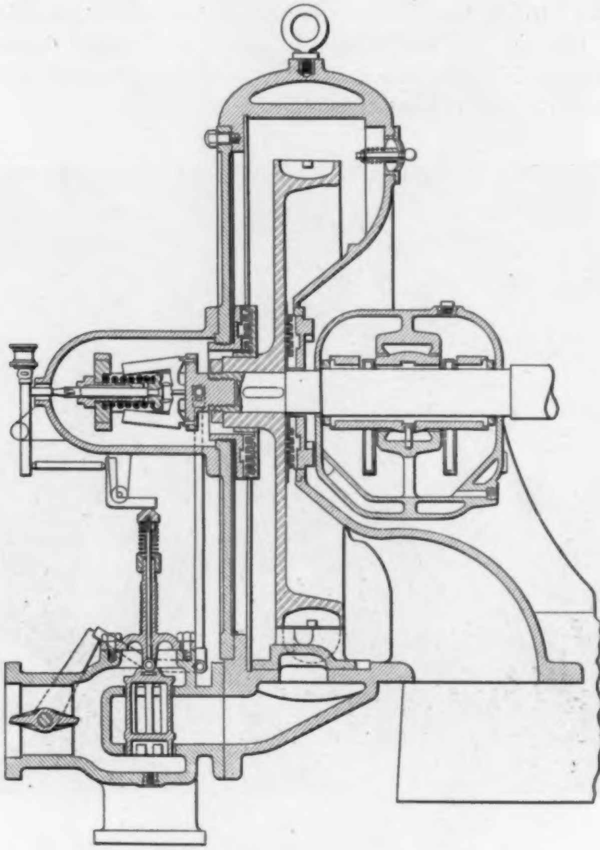

Fig. 11 Sectional View of Bliss Turbine

wheel and are screwed into the stage partitions and held in place by a lock nut.

15 As in large turbines, details of these small turbines, to which reference has been made, show the skill and knowledge of the designer, and that the same problem may be solved in different ways is well illustrated by the sections here reproduced.

DESCRIPTION OF DETAILS

16 *Nozzles.* The diverging nozzle is used by all makers except Kerr, whose multi-stage wheel requires a converging nozzle. In the De Laval, Sturtevant and Kerr turbines, the nozzles are screwed into their seats; that of the Terry is held in place by a bolt. The nozzles

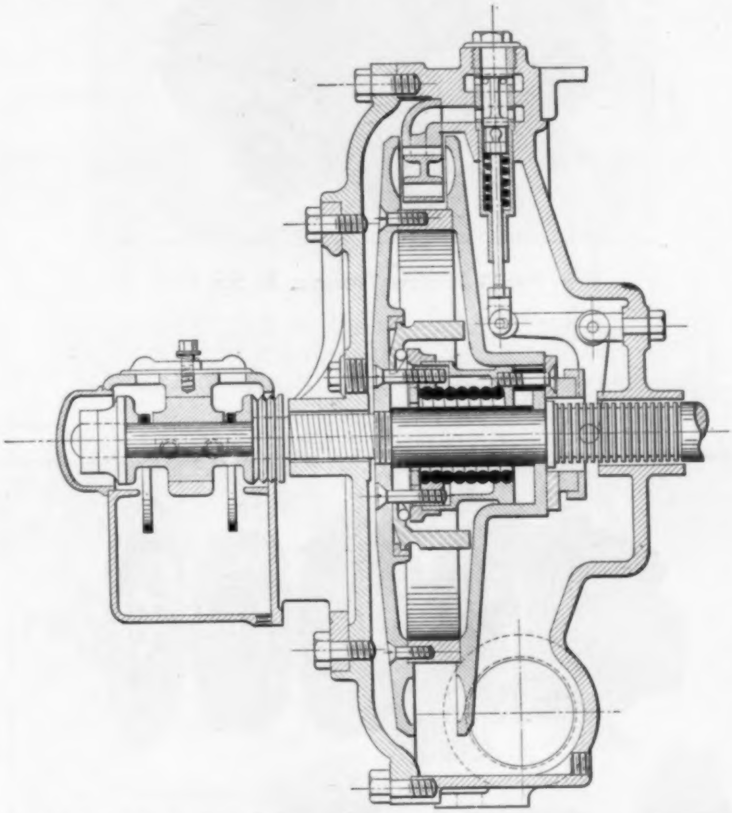

FIG. 12 SECTION OF DAKE HEADLIGHT TURBINE; EXTERIOR SHOWN IN FIG. 9

of the Curtis, Dake and Bliss turbines are reamed out of the solid. The larger sizes of the De Laval machine which have been put on the market lately have a large number of reamed nozzles instead of the older construction.

17 *Buckets.* The constructions employed in the Curtis and De Laval wheels are well-known and have been described many times.

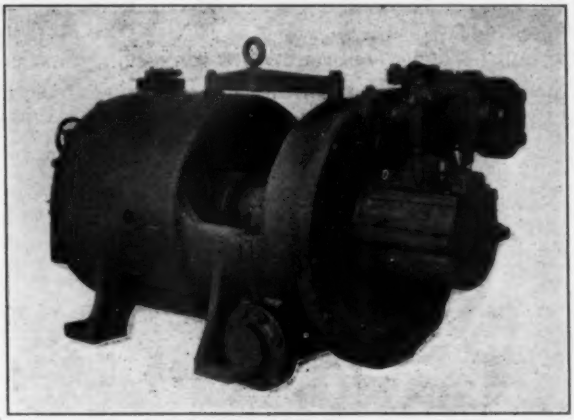

FIG. 13 CURTIS TURBINE, 50 H.P.

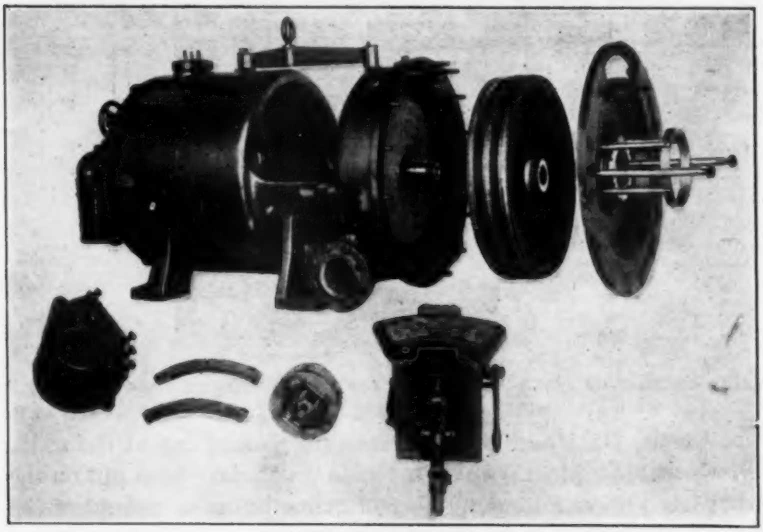

FIG. 14 CURTIS TURBINE IN PROCESS OF ASSEMBLY

The Terry, Dake, Bliss and Sturtevant buckets are practically semicircular in form. The Terry bucket is constructed entirely of steel punchings assembled between grooves in the two steel discs forming the sides of the wheel. The Sturtevant wheel is milled out of a steel casting. The Bliss buckets are milled out, but the partitions are

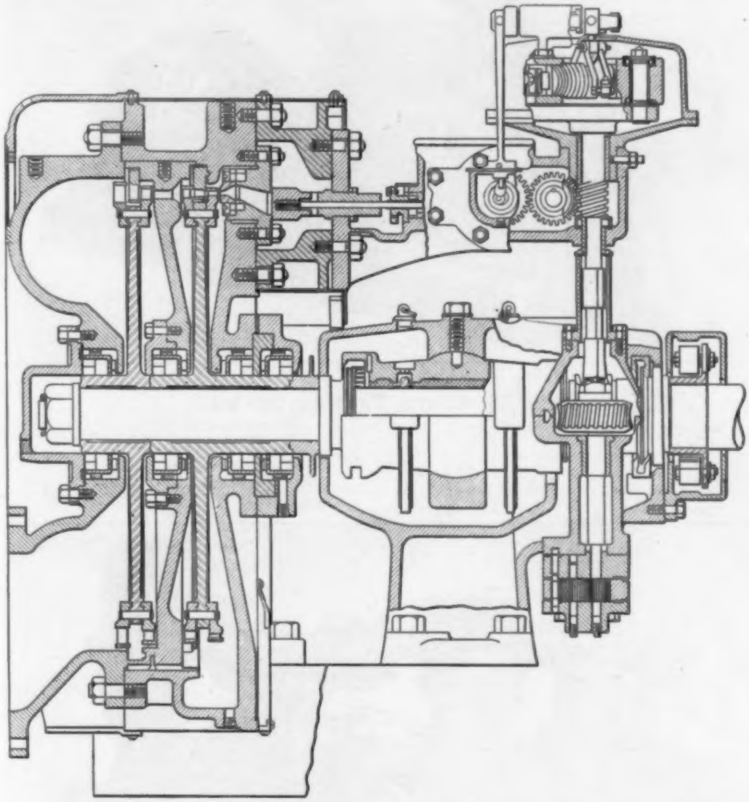

FIG. 15 SECTION OF CURTIS TWO-STAGE, NON-CONDENSING TURBINE, 160 H.P.

inserted and held in place and steel rings are shrunk on. The Dake buckets are turned out of the solid, the recesses for the partitions milled out and the partitions inserted; the wheel is then bolted together. The Kerr buckets are very similar to the original Pelton buckets and are inserted in the wheel in a manner similar to the De Laval buckets.

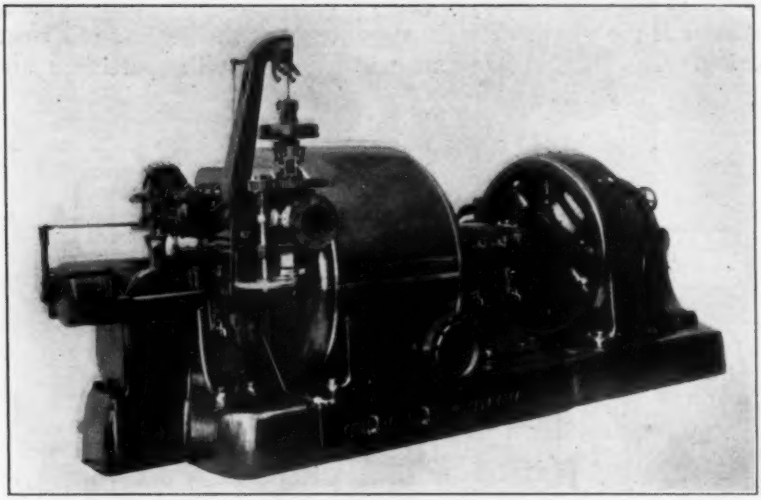

Fig. 16 Curtis Turbine, 200 h.p.

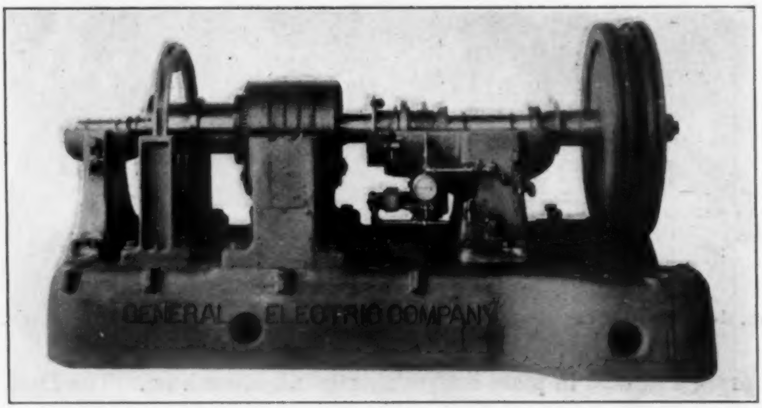

Fig. 17 Revolving Element of Curtis Turbine in Bearings

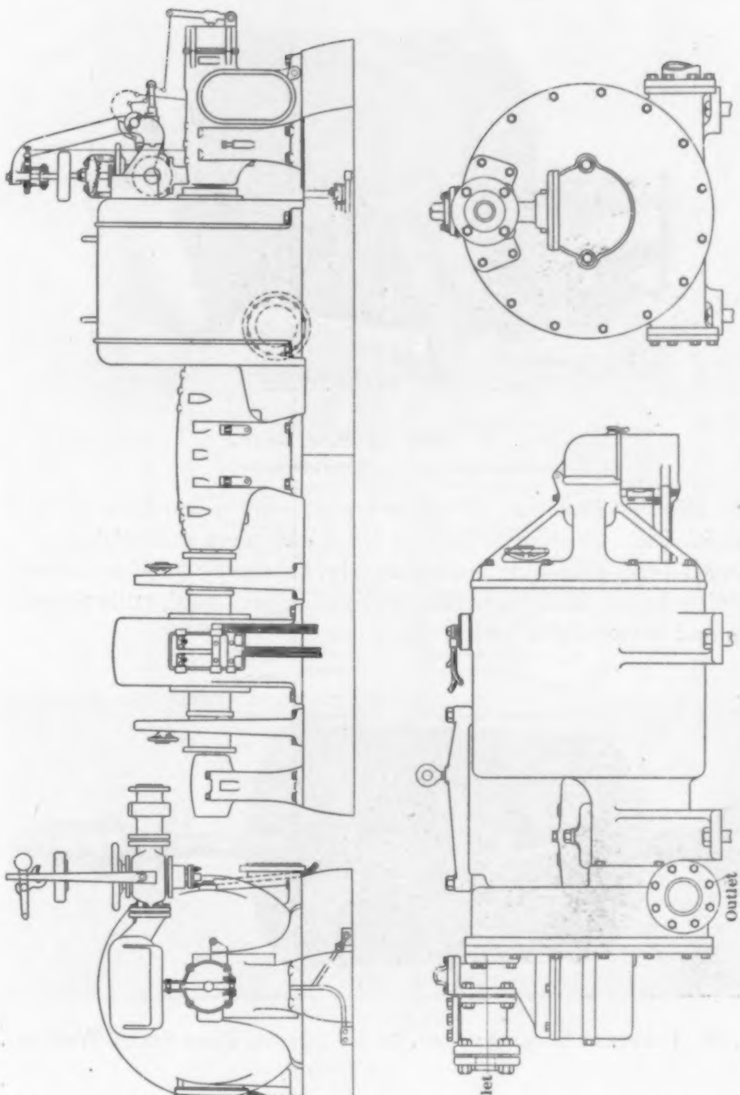

FIG. 18 DIAGRAMS OF CURTIS TURBINES, 200 H.P. AND 50 H.P.

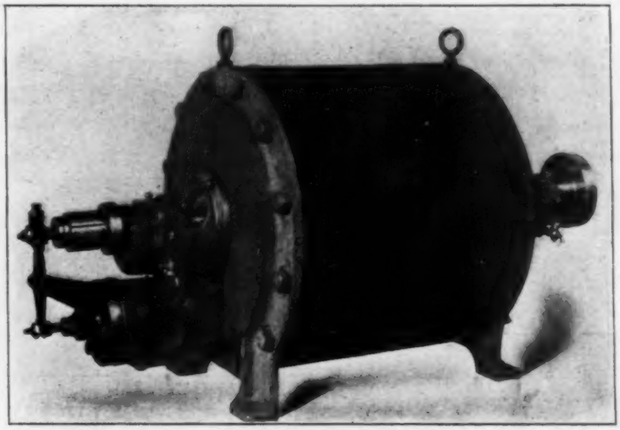

FIG. 19 KERR TURBINE, 18-IN.

18 *Return Chambers.* The Sturtevant returns are milled out of the solid ring. Bliss casts them in the nozzle piece and finishes them by hand; Terry casts each one separately, finishes by hand and assembles with bolts; Dake casts the return chambers solid, mills the passages and covers them with a shrouding.

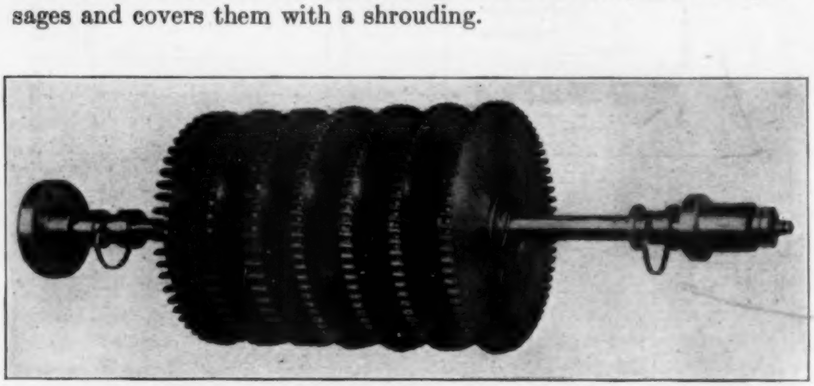

FIG. 20 COMPLETE ROTATING PART, 18-IN., 7-STAGE, KERR STEAM TURBINE

19 *Wheel Centers.* De Laval, Curtis, Sturtevant and Bliss make the wheel centers of steel castings or forgings integral with the wheel. Terry uses a steel casting but bolts the wheel disc to it. Kerr uses a screwed coupling, the inner part cut in three pieces and keyed to

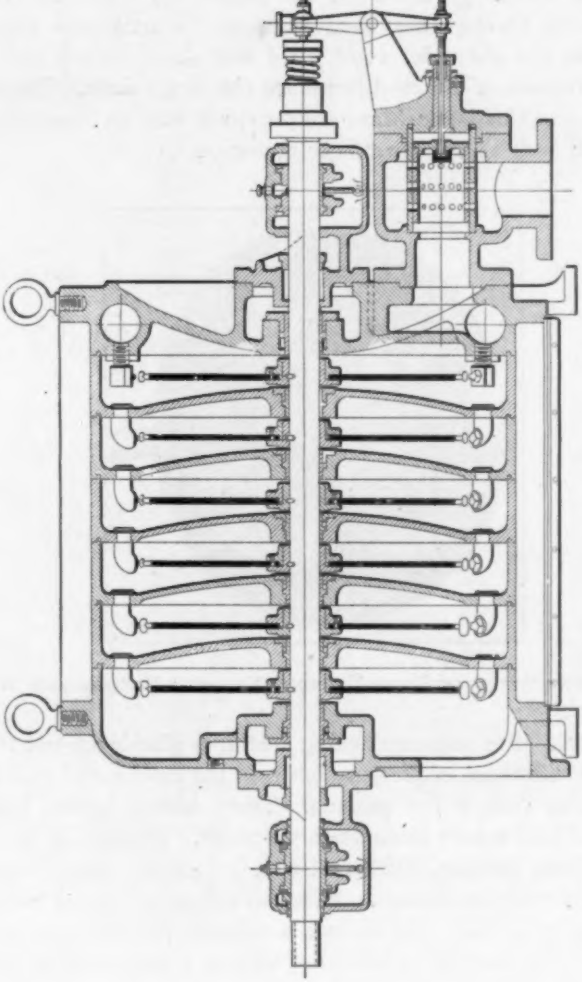

FIG. 21 KERR TURBINE, SECTIONAL VIEW

the shaft with round keys, clamping the wheel disc. Dake's wheel centers are an integral part of the wheel in small sizes, but in the larger machines are steel castings, in some cases a part of the shaft.

20 *Governors.* De Laval, Terry, Sturtevant, Bliss, Dake and Kerr use a flyball governor on the shaft end, which actuates the throttle valve through a system of levers. Curtis uses the flyball governor on the shaft for small sizes and slower-speed spring-controlled governors of different forms for the larger sizes. The Sturtevant, Bliss and Curtis machines are provided with an emergency stop governor as well as the throttling governor.

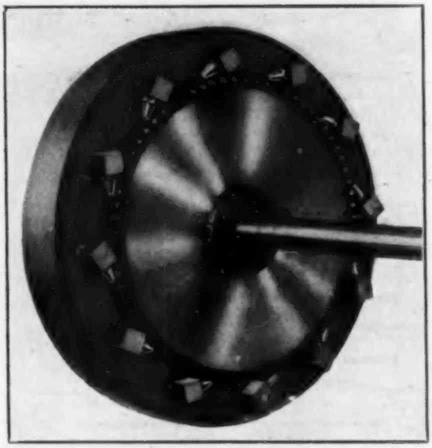

FIG. 22 ONE STAGE OF KERR TURBINE, SHOWING NOZZLES AND WHEEL

21 *Glands.* For non-condensing machines glands are not troublesome, as the difference of pressure between the casing and atmosphere is rarely more than a few pounds. Terry uses a bronze ball-and-socket gland with a long loose fit on the shaft. Sturtevant and Dake use a set of ring packing, either cast-iron or bronze. Bliss has a labyrinth packing without contact. Kerr has a floating bronze bush with soft packing behind it. Curtis uses a metallic packing held in place by a gland-ring, and for condensing service a carbon-ring packing, steam-sealed.

22 *Clearance.* In none of these machines is clearance an important factor. The clearance between buckets and guide-passages on a 24-in. wheel is usually from $\frac{1}{16}$ in. to $\frac{3}{32}$ in. when hot. Striking or rubbing is practically unknown.

23 *Thrust.* Theoretically, there should be no thrust in any turbine of these types. Practically, there is always a very small

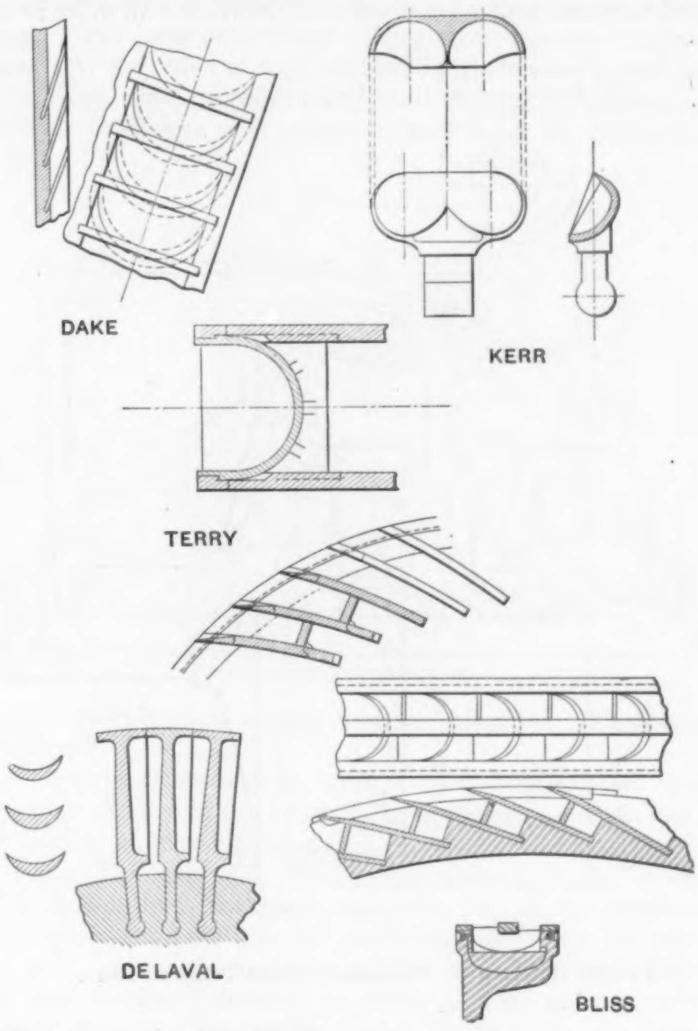

FIG. 23 TYPICAL TURBINE BUCKETS

thrust one way or the other. This thrust is usually taken care of by small thrust-collars or washers next to the bearings. Thrust from

the outside is prevented by the use of a flexible coupling between the turbine and the machine it drives.

24 *Bearings.* The bearings are always ring-oiled with large oil reservoirs, sometimes, on the larger sizes, provided with water jackets

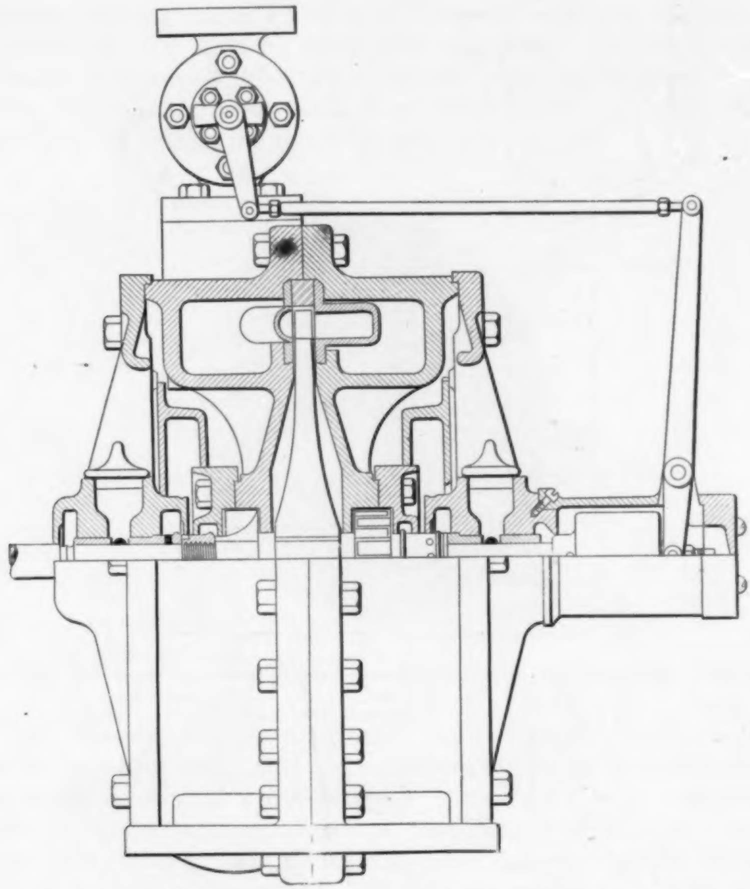

FIG. 24 SECTION OF WILKINSON STEAM TURBINE, 20-IN.

or water cooling pipes for an emergency cold-water circulation. The lubrication of the thrust is obtained at the same time.

25 *Operation.* These machines are nearly automatic in their operation. When the machine is once properly set, the coupling properly adjusted and the bearings supplied with oil, the machine may

run for years without an overhauling. The bearings must be looked after to see that no heating takes place and that the ring is carrying the oil to the shaft. The coupling should be examined from time to time to make sure that no thrust is communicated through it to the turbine. With these precautions a three months' continuous run is common and a number of turbines have to my knowledge run more than eighteen months without a cent spent on them for maintenance. Apparently there is no wear in nozzles, buckets, or return chambers.

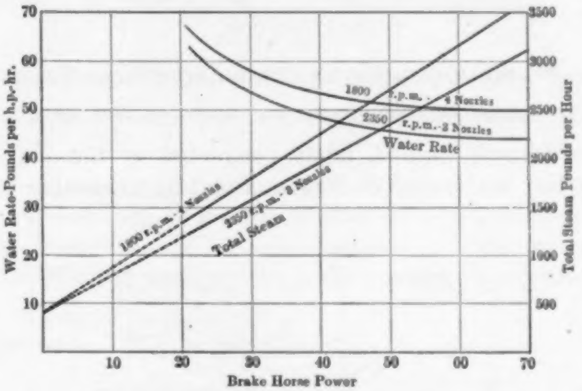

FIG. 25 STEAM CONSUMPTION CURVES, TERRY TURBINE

24-IN. WHEEL, 150-LB. PRESSURE, NO SUPERHEAT, NON-CONDENSING. TESTED BY WESTINGHOUSE MACHINE CO., PITTSBURG, PA.

The only wearing parts are the bearings and these are generously proportioned.

26 These machines may be taken apart and reassembled in half a day; some of them in two hours. The over-hung machines may be overhauled in an even shorter time.

27 *New Turbines.* The Hachenberg turbine, made by Wm. Gardam & Son, New York, is a compound impulse turbine resembling in construction the Dow turbine so frequently illustrated twenty years ago. Some experimental machines have been built, one of which was tested at Columbia University, and the commercial machine will soon be on the market.

28 James Wilkinson, of Providence, R. I., has a small steam turbine nearly in the commercial stage. A number of these machines are running, and within the next few months it is expected they will be on the market.

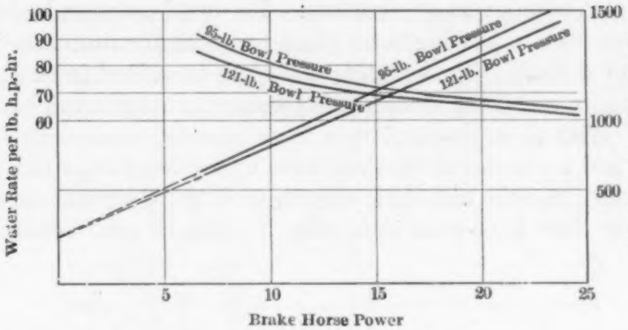

Fig. 26 Steam Consumption Curves, Sturtevant Turbine

20-in. wheel, single-stage, non-condensing, 2400 r.p.m.

29 The Church turbine, lately completed by the Watson-Stillman Company and tested at Stevens Institute, is another promising turbine.

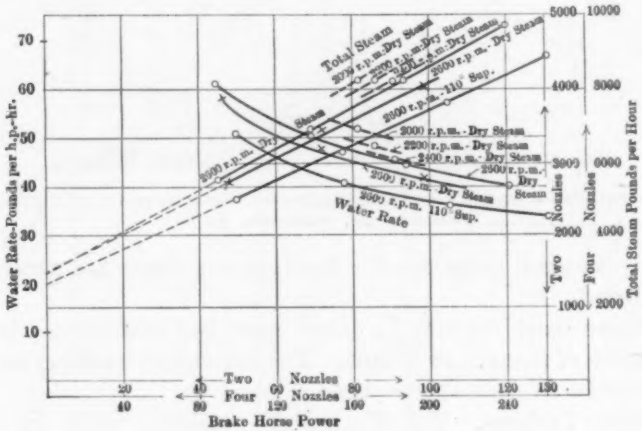

Fig. 27 Steam Consumption Curves, Bliss Turbine, Non-Condensing

Tested by F. L. Pryor at Hoboken, N. J.

O = Two-nozzle, X = Four-nozzle

STEAM ECONOMY

30 The curves of steam economy have in most cases been obtained from the manufacturers. For the Curtis turbine speed-economy

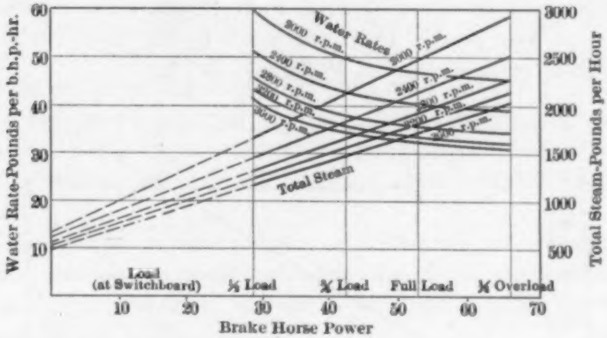

FIG. 28 STEAM CONSUMPTION CURVES, 200-H.P. CURTIS TURBINE

THREE-STAGE, 36-IN. WHEEL, CORRECTED TO 165-LB. ABS. BOWL PRESSURE, NO SUPERHEAT, NON-CONDENSING

curves are given for the 50 h.p. and 200 h.p. sizes. These curves represent the average of a large number of tests and have been corrected to bring them to standard conditions. The averages were consistent, and the variation from the average in any case was not large.

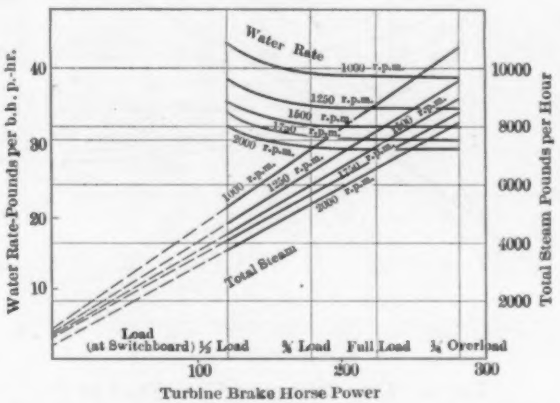

FIG. 29 STEAM CONSUMPTION CURVES, 50 H.P. CURTIS TURBINE

ONE-PRESSURE-STAGE, THREE ROWS OF BUCKETS, 25½-IN. WHEEL, CURVES CORRECTED TO 150-LB. BOWL PRESSURE, NO SUPERHEAT, ATMOSPHERIC EXHAUST

31 The curves for the Terry turbine were plotted from fourteen tests made at East Pittsburg by the Westinghouse Machine Company. The curves for the Bliss turbine were plotted from twenty-four tests

made at Stevens Institute by Prof. F. L. Pryor. The curves for the Kerr turbine were plotted from tests made by the Kerr Turbine Company in their testing plant at Wellsville, N. Y.

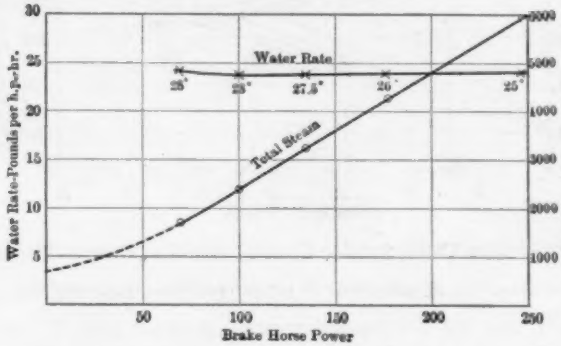

FIG. 30 STEAM CONSUMPTION CURVES, 24-IN. KERR TURBINE

SIX-STAGE, CONDENSING, VARYING VACUUM, 70-LB. PRESSURE-GAGE

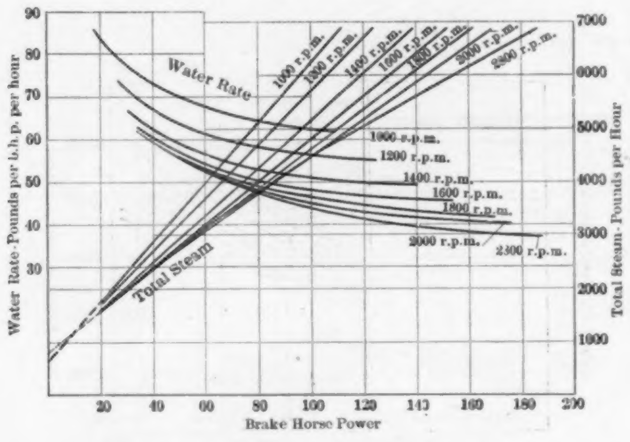

FIG. 31 LOAD CURVES OF KERR TURBINE

24-IN. WHEEL, 8-STAGE 175-LB. GAGE, NON-CONDENSING

32 There seems to be no change in steam economy use. It may be too early to make this statement, but machines running regularly for three years have shown no increase in steam consumption.

33 The field of the small steam turbine is somewhat narrow when

compared with the high-speed steam engine. The small turbine has its place, however, and with the development of a more economical machine at the lower speed ranges, will have a much wider field. The turbine-driven centrifugal fan, for both high and low pressures, will have an increasing use, and the centrifugal turbine-driven pumps have marked advantages over reciprocating apparatus because of the absence of shock on the pipe line and their adaptation to space conditions.

34 The promise of development on these lines has led many manufacturers to enter the small-turbine field and the great expansion of the large-turbine business without doubt presages a like future for the small steam turbine.

OPERATION OF A SMALL PRODUCER GAS-POWER PLANT

By C. W. Obert, New York
Associate Member of the Society

It has been the practice of the packing house of Swift & Company of Chicago, in the distribution of meats and provisions to retailers, to establish in different cities distributing depots with the necessary power equipment for the handling and refrigeration of the products. Some of these branches in the larger cities are establishments of considerable size, and with the extensive cold storage facilities required for the large stocks carried, require comparatively large power installations. The new Westchester market, which the company has recently built in New York at 152d Street and Brook Avenue in the Bronx, is a notable installation of this kind, involving a 400-h.p. producer gas-power plant for the operation of both refrigerating and electric generating machinery, which supplies similar service to a number of adjoining depots of other houses.

2 The refrigerating duty at present required embraces the operation of a total cooling system containing over 46,000 ft. of 2-in. pipe, which reaches a maximum of over 100 tons of refrigeration per 24 hours under the most severe summer weather conditions. Two 65-ton refrigerating machines were installed for this service, with equipments in duplicate, owing to the great importance of continuity of refrigeration, particularly in hot weather. A maximum of nearly 90 h.p. is required for compression machines of this size and engines of 100 h.p. were selected for driving them, to provide sufficient capacity for unfavorable or overload conditions.

3 The electrical load, which includes the operation of several electric elevators, fluctuates ordinarily between 30 kw. and 50 kw. but occasionally reaches a maximum of over 60 kw. For this service, duplicate 75-kw. generators were installed, with driving engines of 100

To be presented at the Washington Meeting (May 1909) of The American Society of Mechanical Engineers. All papers are subject to revision.

h.p. This was done to secure uniformity of size and detail in all four of the driving-engines.

4 For gas making, two producer equipments were installed, also in duplicate. One of these is a 200-h.p. producer, intended for the supply of one refrigerating machine and one generator engine when operating at maximum capacity. The other is of 150-h.p. capacity to permit of closer adjustment of the producer capacity to the load at other times.

5 The plant arrangement consists of an engine room in the easterly end of the sub-basement of the market building, and a producer room adjoining, the entire power equipment occupying a total space, including fuel storage, of 48 ft. by about 55 ft. Headroom for the machinery and piping is afforded by the depression of the sub-basement floor to a level 16 ft. below the street, and the omission of the basement floor in this section, giving thus a clear headroom of 18 ft. The machinery space was originally laid out as a single room, but as a result of the requirements of the underwriters, the producer space has been separated from the rest by a 6-in. hollow-tile fire wall, forming a a producer room 20½ ft. by 24 ft. maximum dimensions. Under the 152d Street sidewalk, there is an 11 ft. by 29 ft. room containing pumps and auxiliaries for the power equipment and the building heater; and adjoining this, an 11 ft. by 30 ft. space for fuel storage. The latter has capacity for over 150 tons of coal, which is dumped into it through sidewalk coalholes from wagons in the street.

6 The engines are Rathbun vertical, three-cylinder units, of 100 h.p., rated at 280 r.p.m., built by the Rathbun-Jones Engineering Company, Toledo, Ohio. The two for the electrical service are direct-connected to 75-kw. generators and the other two through silent chain drives to the ammonia compressors of the refrigerating equipment. They are all of the four-stroke cycle, single-acting, enclosed type, and have 12¾ in. by 13-in. cylinders, designed for the above rating when operating on producer gas of not less than 125 B.t.u. per cu. ft. These engines are throttle-governed, a special form of centrifugal flyball governor being used, and have each a one-ton fly-wheel at both ends of the crankshaft.

7 The gas is generated for the engines in a duplicate equipment of Smith suction producers built by the Smith Gas Power Company, Lexington, Ohio. Each equipment consists of a simple shell producer, a wet scrubber and a dry purifier. While the producers differ in rated capacity to permit of more accurate adjustment of their capacity to the power requirements at different seasons of the year.

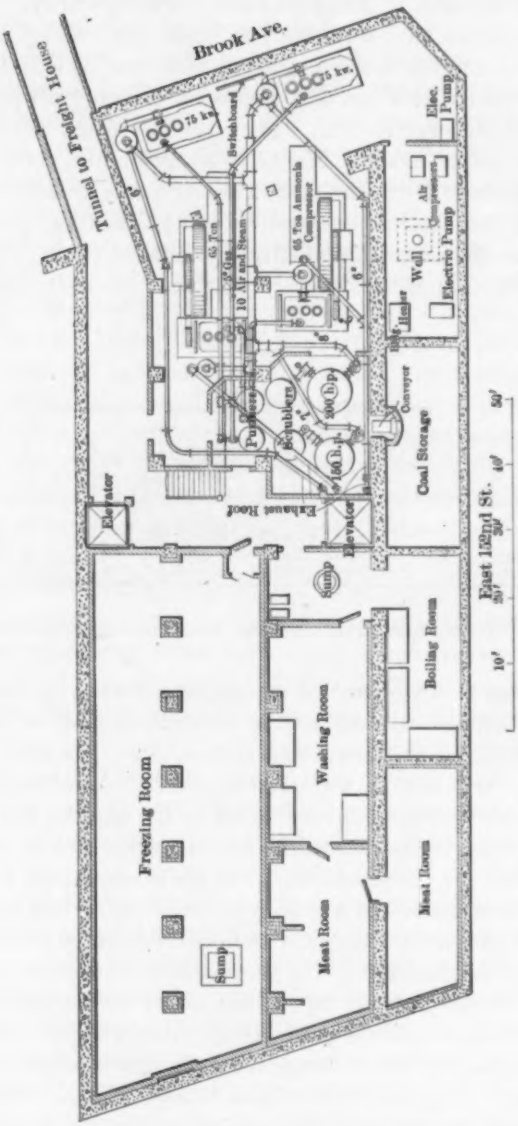

FIG. 1 PLAN SHOWING LOCATION OF MACHINERY, APPARATUS AND CONNECTIONS

the scrubbers and purifiers have a maximum capacity of 200 h.p., which permits the smaller producer to operate up to the maximum plant capacity of 200 h.p., if required to do so temporarily. The small and large producers have 6-ft. and 7-ft. shells respectively, both 12 ft. in height, their internal diameters being $4\frac{1}{2}$ ft. and $5\frac{1}{2}$ ft. respectively, and they are fitted with shaking grates on the up-draft principle for operation with anthracite coal. They are not fitted with attached vaporizers or air pre-heaters, but have an automatic control attachment for regulation of the amount of water vapor to conform to the power requirement and consequent rate of gasification. The scrubbers for cleansing the gas are vertical cylindrical tanks, each 4 ft. in diameter by 15 ft. high, and the dry purifiers have 4-ft. shells 6 ft. in height.

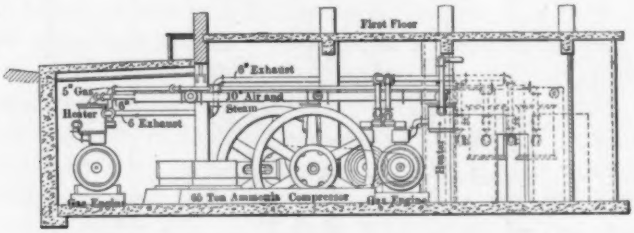

FIG. 2 ELEVATION OF MACHINERY ROOM IN CROSS-SECTION

8 The piping of the plant was somewhat involved by the arrangement of the engines relative to the producers, and, in the Smith producers system, by automatic vaporizers in the exhaust connections to utilize the waste heat of the engines for the vaporization of the water. The vaporizers are located close to the engines and attached to each vaporizer is an automatic device, through which air is admitted and superheated for the producer. The air is conducted to the producers from these devices by a 10-in. pipe main, extending through the engine room, and heavily covered with magnesia insulation.

9 The gas is delivered from the producers by 8-in. pipes connecting from the top of the producer to the bottom of the scrubber shell and each scrubber has a triplicate connection to its corresponding purifier, which is a three-part filter. From these the gas is conducted to the engines through a 5-in. line, with a $3\frac{1}{2}$-in. branch to each. The exhaust connections from the engines to the vaporizers are 5-in. lines and from the latter, individual discharge pipes are carried up for each engine through a pipe shaft in the corner of the building to a roof outlet.

It is to be noted that this arrangement of exhaust connections is effective in so muffling the noise of the escaping gases that they cannot be heard from the adjoining street and are only barely noticeable when on the roof close to the outlets.

10 The electrical generators are 75-kw. General Electric direct-current machines, each rigidly coupled to the driving engine. They are wound to deliver current at 220 volts, the distribution for both lighting and power being on the two-wire system. The electrical circuits are controlled on a three-panel switchboard which contains the usual equipment of indicating and recording instruments, field-rheostat switches and generator and feeder switches. The building is wired separately for lighting and power circuits, and recording watt meters are connected into the feeder circuits for measurement of the power delivered. It is to be noted that separate bus bars are provided for both power and lighting feeders, as well as a switching arrangement by which the lighting service may be supplied from a generator other than that carrying the power load, in case the fluctuations of the latter should interfere with the voltage regulation. This provision has been found unnecessary, however, as the speed regulation of the engines and generators is satisfactory under all fluctuations of loading due to elevator operation.

11 The refrigerating equipment was installed on the direct ammonia expansion system, a feature of which is the connection of all coils in the coolers in series with those in the freezers, whereby all ammonia not thoroughly evaporated in the freezer coils will be in the cooler coils (temperature, 36 deg. fahr.), which permits carrying the freezer temperature at from 0 deg. to + 5 deg. without frosting the compressor. The compressors were built by the Hutteman & Cramer Company, Detroit, Mich., and are horizontal single-cylinder double-acting machines, with 14 in. by 30-in. cylinders, each driven at a speed of 60 r.p.m. by a Renold silent-chain connection from its driving engine, with a speed reduction of about five to one.

12 The ammonia condenser is located on the roof of the building and provided with the usual water-cooling sprays. The water supply for it is obtained from a well extending into water-bearing soil under the basement floor, and the drainage from the sprays is subsequently utilized in the scrubbers and in the engine cylinder jackets. One of the compressor units normally handles the load alone, which leaves one equipment always in reserve, to provide against the serious emergency of a complete stoppage of the refrigerating service during hot weather.

13 In operation this plant has proved particularly economical, largely due to the continuous character of the service resulting from the operation of the refrigeration plant 24 hours a day, seven days a week, thereby eliminating standby losses. The average load range of the plant is ordinarily from 50 per cent (100 h.p.) to full rated load (200 h.p.), the high and low load factors occurring during the summer and winter months respectively, when the refrigeration requirements are maximum and minimum. With the heavier load factor during the summer months, the fuel consumption has ranged between 3400 and 4800 lb. per 24 hours, the larger figure having been exceeded on only two days in 11 months, and the consumption per horsepower-hour as calculated from station fuel records and observed loads, ranged from 1.4 to 2.0 lb. of coal. The fuel rate has dropped during periods of continuous high loads, to about 1 lb. per horsepower-hour, as based on observed loadings, but the daily average under conditions of ordinary commercial operation is usually greater.

14 The operating conditions during the heavy-load season are indicated in the table at the end of the paper, in which the relation of fuel consumption to load carried is shown for two weeks of similar duty. The variations in the amount of fuel charged from day to day are due chiefly to the differing conditions of the fuel bed in the producer, the removal of a particularly large amount of ashes on any day necessitating a heavy fuel charge. No account is taken of cost of water used in the scrubbers and cooling jackets, as the supply is obtained from a well on the premises without cost other than that of pumping.

15 The fuel used is No. 1 buckwheat anthracite that has been passed over a $\frac{3}{8}$-in. mesh and through a $\frac{9}{16}$-in. mesh screen, with 5 per cent fineness, and costs $3.50 per gross ton delivered in cargo lots. It is charged only at the regular cleaning periods, at each of which from 400 to 900 lb. of coal are fed, after the fire has been cleaned down and the ashes removed from the grate. The fire is cleaned periodically twice every shift, or four times per 24 hr. and requires about an hour per cleaning on the average.

16 In this connection it is interesting to note the comparatively short time required to start a producer into service from the cold, which has been done repeatedly on short notice in about five hours; on December 12 when the 150-h.p. producer was placed in operation to relieve the larger unit, the kindling wood was lighted at 10 a.m. and the gas supply turned onto the engine at 2 p.m., with only about 12-in. of fire zone in the fuel bed. The reliability of a suction producer

operating under a continuous and exacting service of this character is well shown by the duty of the 200-h.p. producer during the summer season of 1908, which when taken out of service on December 12, had been continuously in service 24 hours per day and seven days per week since April 22, a continuous run of 235 days. During that time, it had received no more attention than the four cleanings and chargings per 24 hours.

17 The operating force for the power plant consists of an engineer and an assistant engineer and two producer tenders, who work in two shifts. This force is able to maintain the plant equipment in satisfactory operating condition, as well as the refrigerating and electrical equipment of the depot, and it is worthy of note that the plant has not been shut down for any reason since it was started on February 1, 1908. Experience gained in operation for this period indicates that, contrary to the general opinion, no more attention is required than for a first-class steam plant, the necessary attendance comparing very favorably with that of a high-grade steam plant of the same capacity. Cleanliness of all parts of both producer and engine equipments, and careful adjustments, especially of the latter, are imperative and are the keynotes of successful operation. In order to maintain the equipment in such condition, a thorough and comprehensive operating system has been developed which may be of interest.

18 The operating system involves a detailed and thorough inspection routine that keeps the force well informed as to the condition of the entire equipment and a division of duties tending to favor the maintenance work. To the day operating force is assigned the inspection and adjustments of the engines and repairs to igniters, batteries, etc., while the night force has the work of cleaning all machinery.

19 The regular routine of the day force is in detail as follows: First upon coming on duty at 7 a.m., an examination is made of all moving parts of the two engines in operation, and also of oil levels in lubricators and conditions of water jackets and ignition systems. There are always two engines in operation, one being a generator engine and the other a refrigerating engine, which in the periods of heavier loadings in summer time have a combined load of about 140 h.p. of which fully 75 h.p. is taken by the refrigerating system. Next the water regulation for the steam supply is noted and then the condition of the suction draft on the producer and also on the scrubber and purifier, there being three U-shaped draft gages provided for this purpose, one connected to the gas suction line to the engines, the

second to the gas connection from the scrubber to the purifier and the third to the connection between the producer and scrubber. A uniformity of suction of from 2 in. to 3 in. of water in these three gages indicates a proper condition of the three units, while any unusual suction in any of the connections would indicate an obstruction needing immediate attention. The latter is always clearly indicated as an obstructed condition in the producer, for instance, will raise the suction to as high as 9 in. or 10 in. of water.

20 Next an inspection is made of the producer, the temperatures of different portions of the fire being determined to ascertain the condition of the fuel bed, the existence of cracks or fissures or pockets of unburned coal. To do this, a $\frac{5}{16}$-in. iron rod is pushed into the fire through the side peep holes in the producer shell, held there exactly one minute and then withdrawn, the temperature within being noted from the color of the rod. If the latter is at a uniform cherry red temperature throughout its length, this is taken as an indication of an even fire; but if at a brighter heat or dull in some portions of the rod, there is evidence of unnecessarily high local temperatures due to rapid combustion in fissures in the fuel bed, or of a stagnant condition in dirty or unburnt portions of the fire. The rod is first inserted in the lowest hole and then successively into the upper holes, in order to explore the fire in zones. On withdrawing the rod the operator notes graphically the condition of the fire by marking a line with chalk on the shell of the producer even with the hole, a straight line indicating an even temperature, and a broken line showing the dirty condition, etc. This operation is continued for the four holes and a fuel curve drawn from it which gives a practical idea of how the dirt lies in the producer and shows what quality of gas can be expected. Finding the producer in good order, the scrubber, purifier and connections are examined for unusual temperatures, condition of water flow, etc.

21 In the maintenance work, each engine is shut down after every seven days work of 160 hours for general inspection and cleaning, and thus on Monday mornings it is necessary to start up the two reserve units and transfer the respective loads to them. Before starting up either reserve engine, its igniters are cleaned, which takes about one hour. With the igniters clear and everything in good order, the attendant looks at the draft gage, which is equal in importance to the gage of a steam boiler, to see what gas the engines in operation are drawing and whether the start can be made without interfering with their suction. If there are any doubts the gas is

enriched temporarily by putting about four pails of water in the ash pit of the producer and slicing the fire to work down some hot coals, which, by turning the water into vapor, increase the hydrogen content of the gas and enable the third engine to be started without interfering with the others. After getting the engine warmed up, the load is thrown on and the other engine is shut down. The extra pull on the producer, due to overload from running the three engines and the hydrogen added, has usually so enriched the gas that on cutting out a unit the quality of gas is too rich for the two units operating alone. To counteract this, it is necessary to give additional air to each of the units that remain and then, as in starting, there will be no variation in speed of operation.

22 After the engines have been shut down their inspection is begun by the removal of the back crank case covers and examination of the bearings, crank pins, wrist pins, etc., for necessary adjustments. Besides this the exhaust valves are cleaned and the ignition system checked, which requires about two days, as but one thing is done at a time and then only at times when the load on the plant is not heavy. While the engineer is performing this work, the producer tender prepares to clean and coal the producer, as follows:

23 The method of cleaning is to rake off the ash from the grate table and then poke down around the shell from the top poke holes. Having before him the fuel chart which was noted graphically on the producer shell on coming on watch, the attendant knows what part of the bed requires most poking. Before opening the ash pit doors about the shell, water is placed in the ash pit as before and the hot ashes, dropping down, form sufficient steam to mix with the air coming through the ash pit door and offset any bad effect therefrom. This enables the cleaning to be done without affecting the engines. Having cleaned and poked the fire thoroughly and worked down all the ash so as to leave it as clean as possible, the coaling is then begun, count being taken of each hopper of coal charged. The coal is cleaned by screening if very fine or dirty. Having coaled, the operator slices across the grate so as to relieve the center of the fire and again puts water in the ash pit, this time to cool off the grate after cleaning and to offset the effect of any air that may have gotten in during the operation. The cleaning usually occupies one hour, the amount of coal put in ranging up to 900 lb. After giving the producer time to settle down, the ashes are withdrawn from the ash pit, an average of 1½ ash cans (about 3 bushels) being removed after each cleaning. During the cleaning operation the operator is always on the lookout for any

change in the engine speed due to weak gas on account of opening the ash doors. Should this occur he immediately cuts the air supply to the engine, resulting in a combustible mixture without noticeably reducing the speed. The producer is now good for 6 hours' operation, after which the cleaning is repeated.

24 The refrigerating engines are operated for periods of 84 hours and then gone over. One exhaust valve is taken out of an engine each week, thoroughly cleaned, and reground if necessary, thus insuring attention to each valve once in every three months. Igniters are cleaned weekly and the batteries and ignition system checked. The temperature of the fuel bed of the producer is taken twice a day and a gas analysis is made once a week or oftener if necessary. The average calorific value per cubic foot of gas is 134 B.t.u., based on analysis: CO_2, 8.6 per cent; O, 0.6 per cent; CO, 20.2 per cent; H, 18.5 per cent and N, 52.1 per cent.

TABLE 1 RECORD OF LOAD AND FUEL FOR TWO HEAVY WEEKS

	Electrical Load		Refrigerating Load	Total Load	Coal Charged
	Kw hours[1]	B.h.p. hours[2]	B.h.p. hours	B.h.p. hours	Pounds
Sunday, July 25, 1908	332	556	2010	2566	3600
Monday, July 26	400	600	2030	2630	3900
Tuesday, July 27	404	606	2020	2626	3540
Wednesday, July 28	390	585	2020	2605	3180
Thursday, July 29	410	615	2030	2645	4020
Friday, July 30	415	622	2040	2662	4320
Saturday, July 31	403	605	2020	2625	4080
Sunday, August 22, 1908	328	549	2030	2579	3560
Monday, August 23	386	579	2020	2599	3420
Tuesday, August 24	393	589	2020	2609	3600
Wednesday, August 25	392	588	2010	2598	3540
Thursday, August 26	397	596	2010	2606	3840
Friday, August 27	391	586	2020	2606	3540
Saturday, August 28	393	590	2020	2610	3720
Totals	5434	8266	28300	36566	.51960

[1] Recorded by watt-hour meters.

[2] Deduced from kilowatt-hours by assuming 80 per cent efficiency for the generator during light-load periods and 90 per cent for the remaining time.

SOME PROPERTIES OF STEAM

By Prof. R. C. H. Heck, New Brunswick, N. J.

Member of the Society

The purpose of this paper is to present some recent experimental results as to two of the fundamental thermodynamic properties of water and steam, and to make certain comparisons between these determinations and the older values used in our steam tables. The two properties considered are, the relation between pressure and temperature of saturated steam, and the specific heat of water.

THE PRESSURE-TEMPERATURE RELATION

2 This relation is, from the point of view of experimental determination, the simplest of the properties of steam, and with accurate instruments and adequate skill can be very precisely measured. For this reason, the results obtained by various experimenters differ by relatively small amounts, and in discussing them we take up a question in the realm of scientific accuracy rather than one concerning effectively correct values for ordinary technical use. For certain purposes, however, it is most important that this relation be truly and accurately known.

3 In *Annalen der Physik*, 1907, vol. 22, p. 609 to 630, is published a paper by F. Henning, On the Saturation Pressure of Steam, in which are gathered together all the determinations that have been made on this relation, from Magnus and Regnault down to that time. These are compared by means of curves, which show, to a large scale, their departures from an assumed standard of reference. This standard is the formula of Thiesen,

$$(t + 273) \log \frac{p}{760} = 5.409\,(t - 100) - 0.508 \times 10^{-8}\,[(365 - t)^4 - 265^4]$$

where t is centigrade temperature and p is pressure in millimeters of mercury. From the comparison and discussion the conclusion was reached that up to 100 deg. cent. this formula is to be accepted, while above 100 deg. the determinations of Regnault are best—not as

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set forth by his formula, but as worked over by Henning, from a selection of his more reliable observations.

4 A new and very accurate determination by Holborn and Henning, over the range from 50 deg. to 200 deg. cent., is fully described in *Annalen der Physik*, 1908, vol. 26, p. 833 to 883, in a paper, On the Platinum Thermometer and the Saturation Pressure of Steam, while in *Zeitschrift des Vereins deutscher Ingenieure*, February 20, 1909, is given a brief presentation and comparison of results. Exceedingly close agreement is shown between these new observations, the recomputed Regnault values, and the work of Knoblauch, Linde, and Klebe —see Table 3 in *Zeitschrift* article. The final result is a table giving p for every degree from 0 deg. to 205 deg. cent., which follows Thiesen's formula up to 50 deg., and embodies the authors' work from that point.

5 This table is here reproduced in Table 1, but with pressure converted to pounds per square inch and interpolated for every degree fahrenheit from 32 deg. to 402 deg., or to just past 250 lb. abs. Later the writer hopes to extend this table, carrying forward the line of the Holborn-Henning determination in comparison with the observations of Regnault and others. This can be done even up to a pressure of 1000 lb. with sufficient accuracy for all practical purposes.

6 In the work of conversion and interpolation, it was necessary to carry the numbers to a higher degree of apparent accuracy, or to use more significant figures, than any experimental precision would call for. Without a mathematical formula, a function of this sort can be carried forward only by carefully smoothing out the differences until those of the second order follow a continuous rate of change. In this operation, the first differences were brought to a sufficient degree of smoothness to furnish effectively accurate values of the rate of change of p with t; and this differential coefficient, $\frac{dp}{dt}$ is also given in Table 1. It may be considered absolutely correct (as a derivative) within about four or five units in the last place, while as between successive values the closeness is much better. This is less precise than might be desired, but it is accurate enough for use in calculating specific volume, since the thermal data there involved are not of any greater degree of reliability.

7 In Fig. 1 is given a comparison between the pressures in Table 1 and some hitherto generally used values. The base is temperature fahrenheit, the ordinate the difference between the other value of p and that in Table 1. Curve 1, for the range up to 225 deg. fahr., is

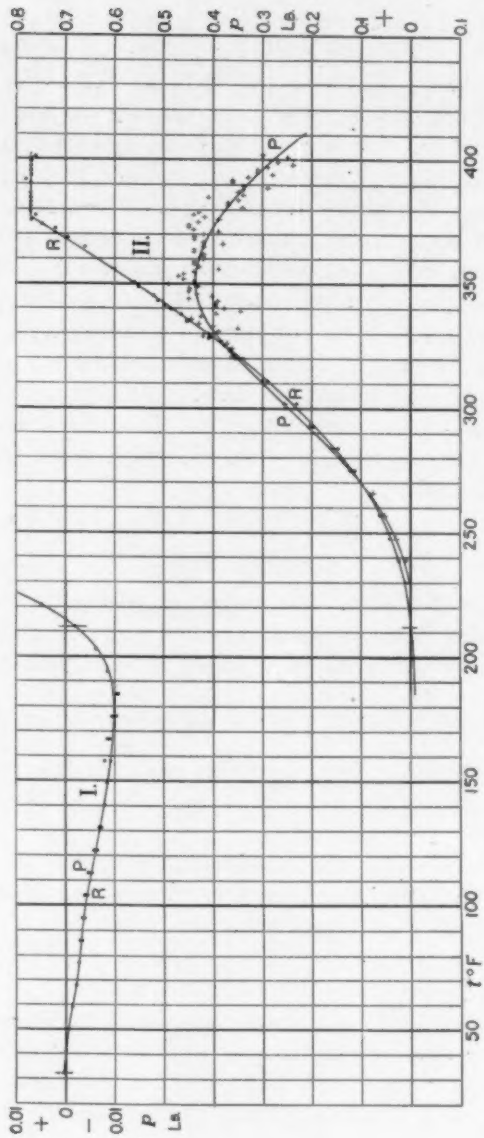

FIG. 1 COMPARISON OF PRESSURE-TEMPERATURE DETERMINATIONS

DIAGRAM SHOWS DEPARTURE OF REGNAULT (R) AND PEABODY (P) VALUES OF THE PRESSURE p FROM THOSE OF HOLBORN AND HENNING, AS GIVEN IN TABLE 1

drawn to the large scale at the left, and shows how Regnault's formula drops below the new determination. The curves at 2 have the ordinate scale at the right, only one-tenth as large as that for 1. The letter R marks the "standard" Regnault curve, here plotted from the table in Roentgen's Thermodynamics, which happened to be the most convenient in its manner of expression: note the abrupt change at about 380 deg. fahr. Curve P shows Peabody's values, which are based on Regnault, but with revised computations, and depart quite decidedly from the older table above 325 deg. The scattering of the points above that temperature is due to the coarseness of numerical expression, Peabody giving but one decimal place for the higher pressures. The curve is simply sketched through this band of points.

8 Holborn and Henning do not attempt to devise a formula, but base their table on a method of graphical interpolation. It will be noted that Curve 1 shows a faint waviness, indicating some departure from perfect mathematical smoothness; but the extreme smallness of the irregularities is really a proof of the skill with which the original interpolation was made.

THE SPECIFIC HEAT OF WATER

9 In Fig. 2 are plotted several important curves for the specific heat of water—the true or instantaneous, not the mean value. Curve R shows Regnault's formula, which in fahrenheit units is,

$$c = 1 + 0.0000222\ (t - 32) + 0.000000278\ (t - 32)^2$$

This curve differs radically from the newer and true determination of the specific heat over the lower part of the range, as shown by the other curves.

10 Curve B represents the experiments of H. T. Barnes and associates; these are described briefly in *Proceedings Royal Society*, 1900, vol. 67, fully in *Phil. Trans. Roy. Soc.*, 1902, vol. A 199; while in *Physical Review*, 1902, vol. 15, there is a description of the determination on supercooled water, which was carried to −5 deg. cent., and the tabulated values for the whole range up to 95 deg. cent. The body of this work was done by a continuous method, water flowing through a small tube and absorbing heat which was electrically supplied and measured: for the range below freezing, a method of mixing was found necessary.

11 Curve P, which begins at 140 deg. fahr., shows the values used by Peabody above this temperature; below it he accepts the work of Barnes. Peabody's line—it is almost straight—is based on Reg-

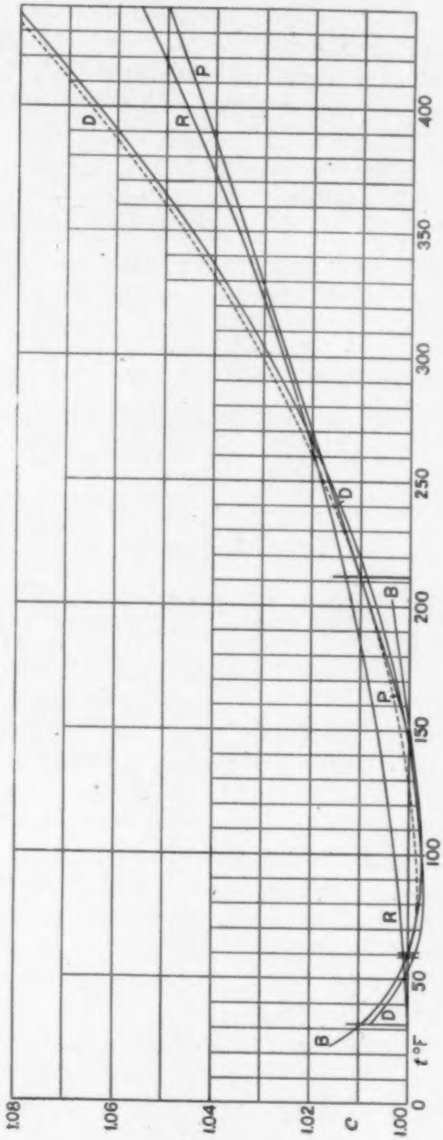

FIG. 2 THE SPECIFIC HEAT OF WATER, VALUES MEASURED OR USED BY REGNAULT (*R*), BARNES (*B*), PEABODY (*P*), AND DIETERICI (*D*)

THE LAST ARE IN MEAN CALORIES; CONVERSION TO THE 15-DEG. CENT. CALORIE RAISES THE *D* CURVE TO THE DOTTED POSITION

nault's experiments: but it hardly seems reasonable to make c thus an almost straight-line function of t.

12 Curve D shows the very important experiments of Dieterici, described in *Annalen der Physik*, 1905, vol. 16. In these a small body of water, pure and free from air, was sealed in a tube of quartz. This little cartridge was heated to a certain desired temperature, then dropped into a Bunsen ice calorimeter, where the heat given off in its cooling to 0 deg. cent. is measured. The highest temperature reached was about 300 deg. cent. The drawback in this method is the relatively large heat capacity of the quartz tube, which has to be very carefully determined. From 100 deg. fahr. upward, Dieterici finds that his results conform very well to a parabolic equation like that of Regnault, which for fahrenheit units has the constants,

$$c = 0.99827 - 0.0000576\ (t - 32) + 0.00000064\ \ (t - 32)^2$$

Below 100 deg. fahr., tabulation from graphical interpolation is preferable to expression by formula. A numerical comparison of the several curves is given in Table 2.

DIFFERENT HEAT UNITS

13 Before discussing these data, something must be said as to the unit of heat measurement. Regnault intended to use the heat capacity of water at 15 deg. cent. as the heat unit—in other words, the 15-deg. calorie—but it was not until long after his time that the true manner of variation of the specific heat over the lower range of ordinary temperatures was either clearly perceived or accurately measured. Barnes' values are based on unity at 16 deg. cent., and it will be noted that the B curve on Fig. 2 crosses the base-line at just about 16 deg. cent. (the two short vertical cross-lines near 60 deg. fahr. are at 15 deg. and 16 deg. cent.). The now generally used numerical values of the mechanical equivalent of heat, 427 m-kg. or 778 ft. lb. are based on a heat unit at 15 deg. cent or 59 deg. fahr.

14 Dieterici's results are expressed in the mean calorie, which is one one-hundreth of the heat required to raise 1 kg. of water from 0 deg. to 100 deg. cent.; and his specific heat values check up to an average of unity over this range. Graphically, on Fig. 2, his curve cuts the 15-deg. cent. ordinate at 0.0012 below the unity base-line. In a special experiment, with electrical measurement analogous to that used by Barnes, he made the mechanical equivalent of the mean calorie bear to our standard Rowland value for the 15-deg. calorie the

ratio of the numbers 419.25 to 418.8, or 1.0011 to 1.000,00. Disregarding some uncertainties which may exist in the minds of physicists as to the finality of this determination, it seems reasonable, for engineering purposes, to use this 0.0011 or 0.11 per cent correction in order to change from one system of units to the other.

15 The amount of attention here paid to this small point is justified by the importance given to it through the introduction of the mean calorie to the Society in the recent paper on The Total Heat of Saturated Steam, by Dr. H. N. Davis. Personally, I think we had better transform heat values in this unit by means of the ratio just offered, rather than change our mechanical equivalent of heat from 778 to 778.9.

16 Now the specific heat is the ratio of a certain absolute quantity of heat to an assumed unit quantity. If we use a larger unit, the ratio will be smaller, and *vice versa*. Assuming that the mean calorie is 1.0011 of the 15-deg. calorie, we change Dieterici's values to the 15-deg. unit if we increase them by 0.11 per cent. This would raise his curve to the dotted position on Fig. 2, and change his formula to

$$c = 0.99938 - 0.00005766 \ (t - 32) + 0.0000006407 \ (t - 32)^2$$

SPECIFIC HEAT OF WATER—CONCLUSION

17 It is pretty safe to say that the Holborn-Henning results for pressure and temperature, set forth in Table 1, are final, and that this relation is now known surely and accurately enough for all purposes of practical science. But in regard to the specific heat of water we are yet confronted by one of the annoying uncertainties which have so long surrounded many parts of this subject. Dieterici claims an experimental accuracy ranging from 0.1 per cent at low ranges to 0.5 per cent at high ranges of temperature: but his method is open to the objection that two heat-capacities have to be measured and their difference used.

18 In spite of some small doubt as to the accuracy of Dieterici's results, and a faint suspicion that his curve may rise too rapidly, I am of the opinion that his determination is to be accepted instead of Regnault's. Further, the idea of an increasing rate of increase in c, as expressed by a second-degree equation, seems to be far more reasonable than that of a nearly constant rate of increase.

19 It is hardly probable that the heat capacity of water will ever be so accurately determined that the heat for the external work of expanding the water will be more than a small fraction of the probable error in heat measurement.

TABLE 1 THE PRESSURE-TEMPERATURE RELATION

t	p	dp/dt	t	p	dp/dt	t	p	dp/dt	t	p	dp/dt
....	....	....	76	0.4433	0.01467	121	1.7362	0.04815	166	5.459	0.1277
32	0.0886	0.003575	77	0.4582	0.01510	122	1.7849	0.0493	167	5.588	0.1302
33	0.0922	0.00371	78	0.4735	0.01554	123	1.8348	0.0505	168	5.719	0.1327
34	0.0960	0.003845	79	0.4893	0.01600	124	1.8859	0.0517	169	5.853	0.1353
35	0.0999	0.003985	80	0.5055	0.01646	125	1.9382	0.05295	170	5.990	0.1380
36	0.1039	0.00413	81	0.5222	0.01694	126	1.9918	0.0542	171	6.129	0.1407
37	0.1081	0.00428	82	0.5394	0.01742	127	2.0466	0.05545	172	6.271	0.1434
38	0.1125	0.00443	83	0.5570	0.01792	128	2.1027	0.05675	173	6.416	0.1462
39	0.1170	0.004585	84	0.5752	0.01844	129	2.1601	0.0581	174	6.564	0.1490
40	0.1217	0.004745	85	0.5939	0.01898	130	2.2189	0.05945	175	6.714	0.1519
41	0.1265	0.00491	86	0.6132	0.01952	131	2.2790	0.0608	176	6.868	0.1548
42	0.1315	0.005075	87	0.6330	0.02008	132	2.3405	0.06215	177	7.024	0.1577
43	0.1367	0.00525	88	0.6533	0.02065	133	2.4033	0.06355	178	7.183	0.1607
44	0.1420	0.00543	89	0.6743	0.02123	134	2.4675	0.06495	179	7.345	0.1637
45	0.1475	0.00561	90	0.6958	0.02182	135	2.5332	0.06645	180	7.511	0.1668
46	0.1532	0.00580	91	0.7179	0.02243	136	2.6004	0.0680	181	7.679	0.1699
47	0.1591	0.00600	92	0.7406	0.02305	137	2.6692	0.0696	182	7.850	0.1730
48	0.1652	0.00620	93	0.7640	0.02368	138	2.7396	0.0712	183	8.025	0.1762
49	0.1715	0.00641	94	0.7880	0.02432	139	2.8116	0.0728	184	8.203	0.1794
50	0.1780	0.00663	95	0.8127	0.02498	140	2.8851	0.0744	185	8.384	0.1827
51	0.1847	0.00685	96	0.8380	0.02566	141	2.9603	0.0760	186	8.568	0.1860
52	0.1917	0.00708	97	0.8640	0.02635	142	3.0371	0.0776	187	8.756	0.1894
53	0.1989	0.00731	98	0.8907	0.02705	143	3.1155	0.0793	188	8.947	0.1929
54	0.2063	0.00754	99	0.9181	0.02776	144	3.1956	0.0810	189	9.142	0.1964
55	0.2104	0.00778	100	0.9462	0.02849	145	3.2775	0.0828	190	9.340	0.1999
56	0.2219	0.00803	101	0.9751	0.02923	146	3.3612	0.0846	191	9.542	0.2035
57	0.2301	0.00829	102	1.0047	0.02999	147	3.4467	0.0864	192	9.747	0.2072
58	0.2385	0.00856	103	1.0350	0.03077	148	3.5341	0.0883	193	9.956	0.2109
59	0.2472	0.00883	104	1.0662	0.03157	149	3.6233	0.0902	194	10.169	0.2147
60	0.2561	0.00911	105	1.0982	0.03240	150	3.7141	0.0921	195	10.385	0.2185
61	0.2653	0.00939	106	1.1310	0.03325	151	3.808	0.0940	196	10.606	0.2224
62	0.2749	0.00968	107	1.1647	0.0341	152	3.903	0.0960	197	10.830	0.2263
63	0.2847	0.00998	108	1.1992	0.0350	153	4.000	0.0980	198	11.058	0.2303
64	0.2948	0.01029	109	1.2347	0.0359	154	4.099	0.1001	199	11.291	0.2343
65	0.3053	0.01061	110	1.2711	0.03685	155	4.200	0.1022	200	11.527	0.2384
66	0.3161	0.01094	111	1.3084	0.03775	156	4.303	0.1043	201	11.767	0.2425
67	0.3272	0.01127	112	1.3466	0.0387	157	4.408	0.1064	202	12.013	0.2467
68	0.3386	0.01161	113	1.3858	0.0397	158	4.516	0.1086	203	12.261	0.2509
69	0.3504	0.01196	114	1.4260	0.0407	159	4.625	0.1108	204	12.514	0.2552
70	0.3625	0.01232	115	1.4671	0.0417	160	4.737	0.1131	205	12.771	0.2595
71	0.3750	0.01269	116	1.5093	0.0427	161	4.852	0.1154	206	13.033	0.2639
72	0.3879	0.01307	117	1.5525	0.04375	162	4.968	0.1178	207	13.299	0.2683
73	0.4012	0.01345	118	1.5968	0.0448	163	5.087	0.1202	208	13.569	0.2728
74	0.4148	0.01384	119	1.6421	0.0459	164	5.209	0.1227	209	13.845	0.2783
75	0.4289	0.01425	120	1.6886	0.0470	165	5.332	0.1252	210	14.124	0.2819

TABLE 1.—Continued

t	p	dp/dt	t	p	dp/dt	t	p	dp/dt	t	p	dp/dt
211	14.408	0.2866	256	33.085	0.5677	301	67.99	1.015	346	127.67	1.675
212	14.697	0.2914	257	33.657	0.5758	302	69.01	1.027	347	129.35	1.693
213	14.991	0.2962	258	34.236	0.5840	303	70.05	1.0395	348	131.05	1.711
214	15.290	0.3011	259	34.824	0.5922	304	71.09	1.052	349	132.77	1.729
215	15.594	0.3061	260	35.420	0.6005	305	72.15	1.065	350	134.51	1.746
216	15.902	0.3111	261	36.025	0.6088	306	73.22	1.0775	351	136.26	1.764
217	16.215	0.3162	262	36.638	0.6172	307	74.31	1.090	352	138.04	1.782
218	16.534	0.3214	263	37.259	0.6256	308	75.40	1.103	353	139.83	1.800
219	16.858	0.3266	264	37.888	0.6341	309	76.51	1.116	354	141.64	1.818
220	17.187	0.3319	265	38.526	0.6426	310	77.64	1.129	355	143.46	1.836
221	17.521	0.3372	266	39.173	0.6513	311	78.77	1.142	356	145.31	1.855
222	17.860	0.3426	267	39.828	0.6600	312	79.92	1.155	357	147.17	1.874
223	18.205	0.3480	268	40.492	0.6688	313	81.08	1.169	358	149.06	1.893
224	18.556	0.3535	269	41.165	0.6777	314	82.26	1.182	359	150.96	1.912
225	18.913	0.3591	270	41.848	0.6868	315	83.44	1.195	360	152.88	1.931
226	19.275	0.3648	271	42.54	0.6960	316	84.65	1.209	361	154.82	1.951
227	19.643	0.3705	272	43.24	0.7052	317	85.86	1.223	362	156.78	1.970
228	20.017	0.3763	273	43.95	0.7145	318	87.09	1.237	363	158.76	1.990
229	20.396	0.3821	274	44.67	0.7239	319	88.34	1.251	364	160.76	2.010
230	20.781	0.3880	275	45.40	0.7334	320	89.60	1.265	365	162.78	2.029
231	21.172	0.3940	276	46.14	0.7430	321	90.87	1.280	366	164.82	2.049
232	21.568	0.4000	277	46.88	0.7527	322	92.16	1.295	367	166.88	2.069
233	21.970	0.4061	278	47.64	0.7625	323	93.46	1.309	368	168.96	2.089
234	22.379	0.4123	279	48.41	0.7725	324	94.78	1.324	369	171.06	2.108
235	22.794	0.4185	280	49.19	0.7826	325	96.17	1.339	370	173.18	2.128
236	23.216	0.4248	281	49.98	0.7926	326	97.45	1.354	371	175.31	2.148
237	23.644	0.4312	282	50.77	0.8028	327	98.81	1.369	372	177.47	2.168
238	24.079	0.4377	283	51.58	0.8131	328	100.19	1.384	373	179.65	2.189
239	24.520	0.4442	284	52.40	0.8235	329	101.58	1.400	374	181.85	2.210
240	24.967	0.4508	285	53.23	0.8340	330	102.99	1.415	375	184.07	2.231
241	25.421	0.4575	286	54.07	0.8446	331	104.41	1.430	376	186.31	2.252
242	25.882	0.4643	287	54.92	0.8553	332	105.85	1.445	377	188.58	2.274
243	26.350	0.4711	288	55.78	0.8661	333	107.30	1.461	378	190.86	2.296
244	26.825	0.4780	289	56.65	0.8770	334	108.77	1.477	379	193.17	2.318
245	27.307	0.4850	290	57.53	0.8880	335	110.26	1.493	380	195.50	2.341
246	27.795	0.4920	291	58.42	0.8991	336	111.76	1.509	381	197.86	2.364
247	28.290	0.4991	292	59.33	0.9103	337	113.27	1.525	382	200.23	2.387
248	28.793	0.5063	293	60.25	0.9216	338	114.81	1.542	383	202.63	2.410
249	29.303	0.5136	294	61.17	0.9330	339	116.36	1.558	384	205.05	2.433
250	29.820	0.5210	295	62.11	0.9445	340	117.92	1.574	385	207.49	2.456
251	30.345	0.5285	296	63.06	0.9561	341	119.50	1.591	386	209.96	2.479
252	30.877	0.5361	297	64.03	0.9678	342	121.10	1.607	387	212.45	2.502
253	31.417	0.5438	298	65.00	0.9796	343	122.72	1.624	388	214.96	2.525
254	31.965	0.5517	299	65.98	0.9915	344	124.35	1.641	389	217.50	2.548
255	32.521	0.5596	300	66.98	1.0035	345	126.00	1.658	390	220.06	2.571

TABLE 1 Continued

t	p	dp/dt	t	p	dp/dt	t	p	dp/dt	t	p	dp/dt
391	222.64	2.594	395	233.20	2.687	398	241.37	2.759	401	249.75	2.832
392	225.24	2.617	396	235.90	2.711	399	244.14	2.783	402	252.60	2.857
393	227.87	2.641	397	238.62	2.735	400	246.93	2.807			
394	230.52	2.664									

TABLE 2 THE SPECIFIC HEAT OF WATER

Temperature		Regnault	Dieterici	Barnes	Peabody
Cent.	Fahr.				
−5	23	....	....	1.0158	....
0	32	1.00000	1.0075	1.0094	....
+5	41	....	1.0037	1.00530	....
10	50	1.00049	1.0008	1.00230	....
15	59	....	0.9987	1.00030	....
20	68	1.00116	0.9974	0.99895	....
25	77	....	0.9970	0.99806	....
30	86	1.00201	0.9971	0.99759	....
35	95	....	0.9972	0.99735	....
40	104	1.00304	0.9974	0.99735	....
50	122	1.00425	0.9983	0.99800	....
60	140	1.00564	0.9995	0.99910	0.99940
70	158	1.00721	1.0012	1.00035	1.00150
80	176	1.00896	1.0032	1.00166	1.00415
90	194	1.01089	1.0057	1.00305	1.00705
100	212	1.01300	1.0086	(1.0044)	1.01010
120	248	1.01776	1.0157	....	1.01620
140	284	1.02324	1.0244	....	1.02230
160	320	1.02944	1.0348	....	1.02850
180	356	1.03636	1.0468	....	1.03475
200	392	1.04400	1.0605	....	1.04100
220	428	1.05236	1.0758	....	1.04760
240	464	(1.06144)	1.0928	....	....
260	500	(1.07124)	1.1115	....	....
280	536	(1.08176)	1.1318	....	....
300	572	(1.09300)	1.1538	....	....

Regnault: from formula, par. 9. Above 200 deg. cent. his formula is an extrapolation.
Dieterici: from table in original publication, computed by formula from 40 deg. cent. upward.
Barnes: from *Physical Review*, with last value extrapolated.
Peabody: from Steam and Entropy Tables, p. 10.
Dieterici: values in mean calories (heat units), others in 15 deg. cent. units.

MARINE PRODUCER GAS POWER

A COMPARISON OF PRODUCER-GAS AND STEAM EQUIPMENTS

By C. L. Straub,[1] New York

Non-Member

So much interest is exhibited both by the engineering profession and the general public in the application of producer gas power to marine, commercial and naval service, that a brief summary of recent progress in this field appears timely.

2 Any innovation which makes for improvement in present practices, surely, though sometimes slowly, achieves its end. Producer gas power, on impartial analysis, offers so many benefits to marine service that it appears strange indeed that more rapid progress has not been made in its adoption. The delay appears to be due to several causes:

3 The marine public, who since the days of the Clermont have exclusively associated the term "motive power" with "steam," have every reason for demanding exact and conclusive evidence of the superiority of gas power or any other power, before adopting it in lieu of their present methods. This evidence is only now slowly coming forth. Many who have been credited with authority by the engineering profession and others, either through ignorance or through being misinformed, have beset the way of marine gas power with numberless imaginary obstacles, ridiculous in proportion to the real difficulties, but sufficient nevertheless to instill some doubt of the possibilities of the system, into the minds of the waiting public.

4 Only recently has such progress been made in the development of gas power for marine work, as to warrant its early adoption in commercial service. Two years ago, less than 300 h.p. in the aggregate was being developed by marine producer gas power installations; these were experimental in nature and were of the German Capitaine

[1] With the Loomis-Pettibone Co., New York.

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type. There are now installed and accepted 23 Capitaine marine plants, aggregating 2035 h.p., a partial list of which follows:

a Emil Capitaine: Launch, 60 b.h.p.; 4-cylinder single-acting, 4-cycle engine; boat 60 ft. long, 10 ft. beam, 4 ft. deep; ran an average speed of 10 miles for 10 hr. on 412 lb. of anthracite coal.

b Rex: Sea-going Swedish boat; 102 ft. long; 22 ft. beam, carries 350 tons on 9-ft. draft; fitted with a 3-cylinder single-acting, 45-h.p. engine at 300 r.p.m.

c Capitaine: Tow boat at Genoa; length 47 ft., beam 12 ft, draft 7 ft: fitted with a 3-cylinder, single-acting, 4-cycle engine, 105 b.h.p. at 240 r.p.m.

d Duchess: Canal barge; length 71 ft., beam 7 ft. 1 in.; carries 20 tons cargo on 42-in. draft; fitted with double-cylinder, single-acting, 4-cycle engine of 25 b.h.p.

e Dusseldorf: Tug at Hamburg; fitted with a 4-cylinder, single-acting. 4-cycle engine, 60 b.h.p. at 240 r.p.m.

f Isee: Tug, fitted with a 3-cylinder, single-acting, 4-cycle engine, 45 b.h.p., 300 r.p.m.

g Wilhelm: Combination freight and passenger Rhine boat, fitted with a 5-cylinder, single-acting engine, 175 b.h.p. at 240 r.p.m.

h Badenia: Rhine freight boat, fitted with a 2-cylinder, single-acting, 4-cycle engine of 30 b.h.p.

i Katrina: Canal freight boat, fitted with a 3-cylinder, single-acting, 4-cycle engine, 45 b.h.p.

j Marie: Canal freight boat; fitted with a 3-cylinder, single-acting, 4-cycle engine, 45 b.h.p.

k Hoffnung: Combination freight and passenger Rhine boat, fitted with a 5-cylinder, single-acting, 4-cycle engine of 210 b.h.p.

l Amersie: Volga freight boat, fitted with a 4-cylinder, single-acting, 4-cycle engine of 60 b.h.p.

m No. 58: Canal freight boat, fitted with a 4-cylinder, single-acting, 4-cycle engine of 60 b.h.p.

5 In addition to the above there were a number of freight boats, the dimensions and names of which we were unable to obtain, but whose power plants varied in capacity from 30 to 175 h.p. each.

n H. M. S. Rattler: An old gun boat, 165 ft. long, 29 ft. beam, originally fitted with a triple expansion engine. The gas engine is 5-cylinder, single-acting, 4-cycle. Cylinders 20 in. diameter by 24 in. stroke, developing 500 b.h.p. at 120 r.p.m. This engine is started by means of a mixture of gas and air which is pumped into the cylinders at a pressure of about 95 lb. per sq. in. This complete plant was designed entirely in the Capitaine Works at Düsseldorf. The total weight of the entire plant, including the donkey boiler for working the pumps and auxiliaries, is 94 tons, as compared with 150 tons in the case of the displaced steam engine. A consumption of 1525 lb. of coal was made for a measured distance of 45 knots on an average speed of

10½ knots per hr. The cost per mile for fuel with coal at 15*s*. 6*d*. per ton is $0.064 U. S. currency. This boat made a maximum speed of 11.3 knots per hr. against a 1½ knot current at 110 r.p.m. of the engine shaft.

6 All of the above plants by their design and construction are restricted to operation on anthracite coal, coke or hard-burned charcoal, and any plant so restricted by its design to one class of fuel is seriously limited in its scope of application. The development of a simple marine gas-producer for use with any class of solid fuel is a necessity, if the system is to be considered seriously by the marine profession.

7 The writer is fortunate in having been associated with some recent American developments both in stationary and marine gas-power plants, a brief survey of a portion of which will enable us to draw more clearly the comparison between a typical steam and a possible gas installation.

8 There are in commercial operation in this country today, two distinct types of stationary power gas-producers which are suited by their design for operation on almost any class of solid fuel. They may, by their systems of operation, be qualified as up-draft and down-draft producers.

9 In the up-draft producer, the fuel is charged into the generator through an air-tight mechanism at the top, while air and steam, or air and products of combustion are admitted at the bottom of the fuel bed, and passing upward, leave the generator at the top in contact with the fresh fuel. Almost all of the hydro-carbons leave the generator unfixed with the hot gas, only to be condensed later in the gas coolers or scrubbers and gas mains, forming large amounts of tar, which, if not removed to a minute degree, will positively prevent the operation of the engine. The removal of this tar is troublesome and is accomplished at a loss of power and efficiency. The fuel in the upper zone of the bed in the up-draft producers cokes and cakes so seriously as to require continuous poking of the fuel bed, either mechanically or by hand. These features and others in this type of apparatus contribute to limit the rates of combustion per sq. ft. of grate to a relatively low quantity. All things considered, therefore, this type of apparatus has not lent itself agreeably to modification for marine service.

10 In the down-draft type of apparatus, the fuel is charged by hand through a large door at the top of the producer, which is normally in an open position, allowing the operator unrestricted inspection of the whole upper zone of the fuel bed. The hydro-carbons con-

tained in the fuel are driven off in the upper zone, mixed with air and almost completely burned, and the burnt products, passing downward through the relatively deep bed of fuel, are decomposed and regenerated into carbon-monoxid and hydrogen gases. All of the tar and the lighter hydro-carbons are completely fixed in this process, and no tar is found in condensation in any portion of the plant after cooling. Coking or caking of the fuel bed is not detrimental, but on the other hand, assists in keeping the fire in the open porous condition, which is desirable and necessary where high rates of combustion obtain. This feature eliminates the poking necessary in the up-draft apparatus. The gas leaves the bottom of the producer through brick-lined connections, and a portion of the sensible heat is extracted in passing through an economizer. The gas is then cooled and washed and passed through an exhausting mechanism, whence it is delivered under pressure to the engine.

11 This type of apparatus lends itself admirably to the high rate of fuel combustion, which for the sake of economy in space and weight is desirable in marine service. There are in actual commercial operation today, a number of plants of this type having an average fuel consumption of over 40 lb. of good bituminous coal per sq. ft. of grate per hr. These producers are sold on a rating of from 18 lb. to 20 lb. of fuel per sq. ft. of grate per hr., which is almost 100 per cent greater than the average rating of the up-draft type of producers.

12 Undoubtedly a better method of measuring the ability or success of these two systems, is to make note of the number and capacity of plants of each type in actual operation on engine service. A report of the Committee on Gas Engines of the National Electric Light Association, spring of 1908, showed that in gas-engine power plants, of capacities of over 300 h.p. each, there were in operation 32 plants of both types having a total capacity of 57,225 h.p. Of these, 4 plants were of the up-draft type, having an aggregate capacity of 4050 h.p., and 28 plants were of the down-draft type, with an aggregate capacity of 53,175 h.p. The latter contain the Loomis-Pettibone gas-generating apparatus, some of which has been in operation on engine service for 13 years.

13 Three years have been devoted to the modification of these stationary plants for marine service. The work involved a reduction in the size and weight of the generators; complete revision of the scrubbing, gas cleansing and exhausting mechanism; elimination of all gas holders, storage receptacles, mixing chambers, etc.

14 The plant as modified to date has a light compact producer,

which while retaining the same rate of combustion as the stationary apparatus, has materially reduced dimensions and weight of the shells, brick lining, fittings, etc. The economizer boilers which were used on stationary work have been abandoned, and replaced with light air-heating economizers. The gas-coolers no longer contain any coke or broken material, or wooden trays, and are built of very light, non-corrosive sheet metal, and arranged for either vertical or horizontal positions, the latter arrangement being convenient for space which would be otherwise wasted in the vessel. The cooled and partially cleansed gas is drawn through the above portion of the plant by a centrifugal gas-cleaning exhauster, driven by direct-connected motor. The gas passes directly from the exhauster under pressure, through an automatic pressure regulating valve, to the engine manifold.

15 That the plant is adaptable for marine service with regard to space occupied and weight, may be seen from the following conservative estimate:

> Plants of from 100 to 500 h.p. each occupy from 0.4 to 0.5 sq. ft. per h.p., and weigh from 70 lb. to 90 lb. per h.p., including all auxiliaries, piping, etc.; plants of from 500 h.p. to 1000 h.p. occupy from 0.03 sq. ft. to 0.45 sq. ft. per h.p., and weigh from 40 lb. to 70 lb. per h.p., including all auxiliaries, piping, etc.

16 Undoubtedly the rational opportunity at the present time for marine gas power lies in commercial service, in which regard the most rapid advancement in America has been made in the freight, ore and fuel carriers of the Great Lakes.

17 We have therefore taken for our example a ship built from the designs of Messrs. Babcock & Penton within the last year. For the sake of clearness, the views show only the machinery space; all of the ladders, stairways and grates have been omitted from the plans, and the piping is shown only on the gas installation. The machinery installation proper is all there, however, and while the parts eliminated are merely accessory, the contrast between the two plants would be all the more striking were they included.

18 The boat is a modern Lake freighter and represents the best standard practice in this service. She is 306 ft. long over all, 45 ft. beam and 24 ft. deep. Her present power equipment consists of a single-screw, triple-expansion, three-crank condensing engine, 18–30–50 by 36 in. stroke. She indicates 1050 h.p. at 90 to 95 r.p.m. The engine is of the typical box-front columns and condenser back-frame type. She is fitted with direct-connected air pump and has independ-

ent steam-driven reciprocating, circulating, bilge, sanitary and feed pumps. The complete engine room weight, including piping and all auxiliaries, is, in round figures, 182,000 lb.

19 The boiler room equipment consists of two single-ended Scotch boilers 11 ft. 10 in. mean diameter each; 11 ft. length over heads each, operating on a working pressure of 180 lb. per sq. in. Each boiler is fitted with two 42-in. corrugated furnaces and has two hundred and forty-four $2\frac{3}{4}$-in. tubes. The grate surface is $36\frac{3}{4}$ sq. ft. and the heating surface 1642 sq. ft. in each boiler.

20 The boilers are fitted with forced draft from a 66-in. steam-driven fan. The air for the draft is taken from the stoke hole and the fan is located in the engine room. The fan discharge passes through air heaters in the up-take and thence through ducts to the under side of the grates. The complete boiler-room weight, including water in the boilers, but not fuel, is 170,000 lb. These weights are actual figures.

21 The coal bunker extends from the main deck to the tank top and is arranged athwartship. It has a capacity of 170 tons. The bunker doors face the stokers on the stoke hole floor. The bunker is 6 ft. fore and aft at the stoke hole. The distance from the forward to after bulkhead in the boiler room is 24 ft. 0 in. The distance from the forward to the after bulkhead in the engine room is 22 ft. 0 in., making a total over-all length for the plant, including bunkers, of 52 ft. 0. in.

22 The coal consumption on this vessel is from 1.08 lb. to 2 lb. per i.h.p.-hr. This coal is of approximately 13,500 B. t. u. per lb.

23 The problem of substitution of gas for steam, aside from the design of the construction of the gas producers or cylinders of the gas engines, has been thoroughly worked out by Messrs. Babcock & Penton, of Cleveland. The illustrations show two different arrangements of gas producers with the same engine. The proposed gas engine is a four-cylinder, double-acting, reversing type, having cylinders 24 in. bore by 36 in. stroke, delivering 1000 b.h.p. at 100 r.p.m. The reversing is accomplished by means of compressed air, which is used to shift the cams from the head to the stern position. Compressed air is admitted to the cylinders by timed cams in proper cycle. The crank shaft of the engine is rigidly coupled to the tail shaft of the screw.

24 The illustrations show a column-framed engine. Since making this layout, the design of the engine has been modified to meet all of the present marine conditions now found in marine engine design on the Lakes. In fact, with the exception of the condenser shown on the

steam drawings, the gas engine frame will be very similar to the steam engine.

25 For the generation of current to drive the auxiliaries, there will be installed a double-cylinder, double-acting gas engine, direct-connected to a 50-kw. direct-current generator. All of the pumps and auxiliaries will be motor-driven. A smaller direct-connected unit operating on oil will be used for pumping, blowing fires, or other service, when the gas plant is down. Allowing a distance of 4 ft. 3 in. between the forward bulkhead in engine room and the forward side of the flywheel, which distance is one foot greater than that in the steam installation, we have an over-all distance between forward and after bulkheads in the engine room of 19 ft. 6 in.

26 As previously stated, two arrangements of producer room are shown. The first, the four-generator plant, consists of four 6 ft. by 9 ft. generators, each fitted with independent economizers. The forward pair and the after pair are connected independently to two horizontal gas scrubbers, which are shown slung under the main deck beams. The gas passes from these scrubbers to independent motor-driven centrifugal gas-cleaning fans, whence it is delivered, either through common connection to a purge or blow-off pipe which also acts as a by-pass, or through two gas pressure regulator valves to the air and gas mixing valve at the engine manifold. The 6 ft. generators require only one cleaning door each. As a result a single cleaning space suffices for the four machines, allowing them to be grouped with reference to athwartship space, so as to give ample room on each side of the vessel for coal bunkers. The total space occupied by the producer plant is 21 ft. 10 in. athwartship, and 15 ft. between forward and after bulkheads. The producer room weight, including generators, economizers, piping, and scrubbers, complete, of the four-generator set, is 110,000 lb. This weight is estimated, but has been carefully checked and completely covers all the mechanism. In addition to the above mechanism, there will be a heating boiler which is shown on the main deck. This boiler will serve to furnish low-pressure steam for heating the vessel and supplying hot water for washing down decks, etc. This boiler, with water, will weigh about 8000 lb.

27 The two-generator producer plant, which will undoubtedly be the one installed, will consist of two 8 ft. diameter by 9 ft. 6 in. generators, connected to independent air economizers and each fitted with an independent horizontal scrubber, located athwartship under the main deck beams. The gas outlet at the scrubbers will be connected with a cross-over, so that either exhauster may operate either or both

producer plants. The exhausters are installed in duplicate and are connected with common purge or blow-off and common gas outlets leading either through one pressure-regulator valve, or through a by-pass direct to the air and gas mixing valves at the engine manifold.

28 On account of the fact that the 8-ft. generators require two cleaning doors set at 120 deg. the double-generator unit plant will require the full athwartship space in the producer room. The approximate floor space occupied, therefore, will be 30 ft. athwartship and 15 ft. between forward and after bulkheads. The producer-room weight, including generators, economizers, piping and scrubbers complete for the two-generator set, is 82,000 lb. This weight is estimated, but has been carefully checked and completely covers all of the mechanism. As in the case of the four-generator plant, a low-pressure boiler for heating service will be installed. In the two-generator plant, however, this boiler will be located on the producer-operating floor, so that one set of firemen may suffice for both.

29 The only guide we have for estimating the probable fuel consumption for this service is found in the large number of stationary producer gas power plants now in operation. Fortunately, in marine service, the load factor will be uniformly much higher than that found in any stationary service to which gas power is applied at the present time. The builders of this apparatus are prepared to guarantee one brake horse power per hr. on *one* lb. of good bituminous coal, averaging 13,500 B.t.u. per lb.

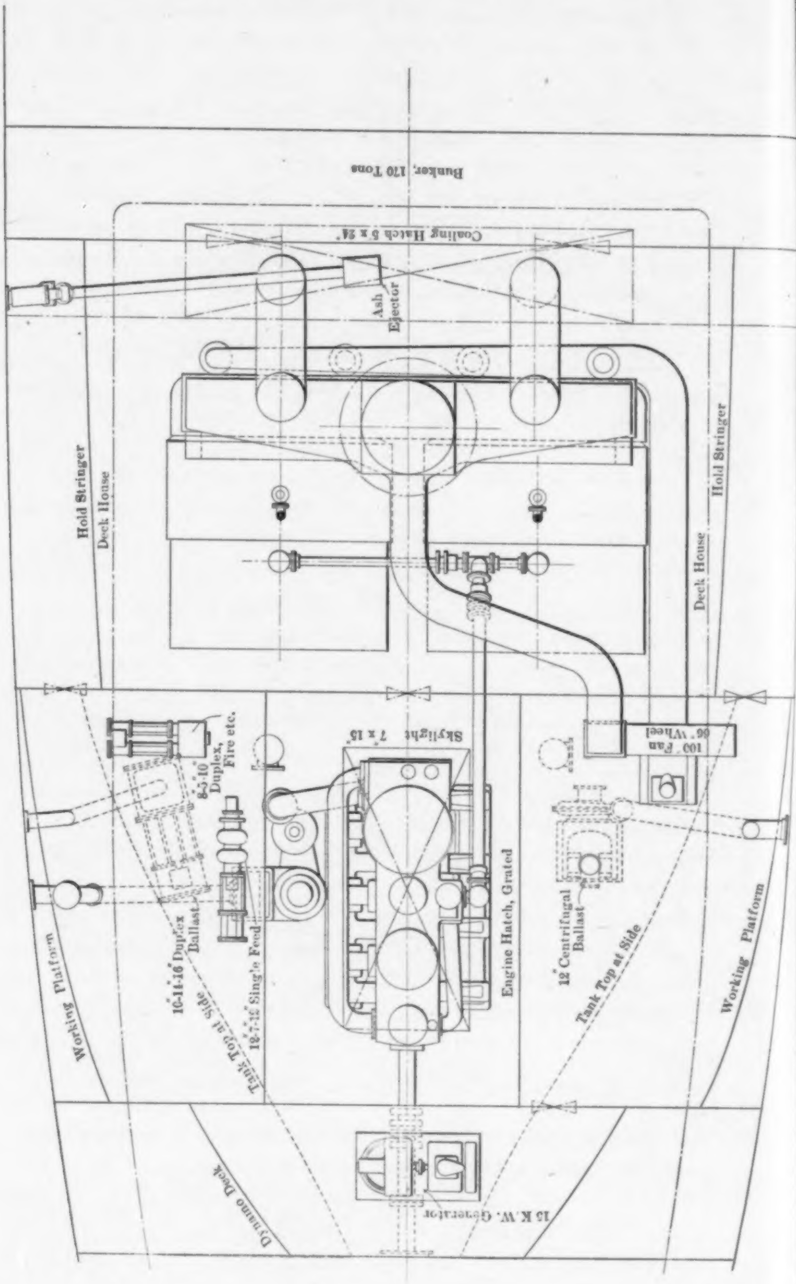
30 Messrs. Babcock & Penton, the engineers who designed and built the steam plant, and who have spent years on the problem of the substitution of gas for steam, have suggested that the coal bunker, which will be placed above the charging deck of the producer, should have a capacity of about 80 tons of coal. These bunkers will run from the charging deck to the deck-house and will have doors opening closely adjacent to the charging doors of the generators, so that little or no coal passing on the operating deck will be required.

31 In making the comparison shown in the table, it is unnecessary to go into the cost of fuel, labor, hours of service, etc., as these elements vary with every class of service. In this particular proposition, it will suffice to state that the engineers who have been working on this substitution problem have conservatively figured that with the saving in fuel and the increased cargo carried, the cost of the complete plant will be saved in two years of operation.

32 While the gas plant here described has neither been constructed nor ordered at this writing, its forthcoming will not be long delayed,

TABLE I COMPARISON OF POWER PLANTS FOR GREAT LAKES FREIGHT-CARRIER

Length over all . . . . 306 ft. 0 in.	Displacement . . . . Tons gross
Beam . . . . 45 ft. 0 in.	Cargo . . . . 4200 net lb., 18 ft. draft
Depth . . . . 24 ft. 0. in.	Speed, 12 statute miles per hr. on 900 i.h.p.
Steam	**Gas**
ENGINE ROOM	ENGINE ROOM
3-cylinder triple-expansion, condensing, 18–30–50 by 36 in., 1050 i.h.p. at 90 to 95 r.p.m.	4-cylinder, 4-cycle, double-acting, gas engine, 24 in. diam., by 36 in. stroke 1000 b.h.p. at 95 r.p.m.
Auxiliaries steam-driven	Auxiliaries motor-driven
Length between bulkheads, 22 ft. 0 in.	Length between bulkheads, 19 ft. 6 in.
Engine room weights, including auxiliaries and piping, 182,000 lb.	Engine room weights, 105,000 lb.
BOILER ROOM	PRODUCER ROOM
2 single-ended Scotch boilers fitted with economizers, forced draught. Length each boiler, overheads 11 ft. 0 in.	Two down-draft gas producers and auxiliaries
Mean diameter, each, 11 ft. 10 in.	Diameter shell, each generator, 8 ft. 0. in.
Two 42-in. furnaces each	Inside diameter, lining generator, 6. ft. 3 in.
244 $2\frac{3}{4}$-in. tubes, each	Height shell, each generator, 9 ft. 6 in.
Grate surface, each, 36.75 sq. ft.	Grate surface, each generator, 30.67 sq. ft.
Heating surface, each, 1642 sq. ft.	
Boiler room weight, water in boilers, no fuel, 170,000 lb.	Producer room weights, no water, no fuel, 82,000 lb.
Length boiler room 24 ft. 0 in.	
Length boiler room, includes bunkers, 30 ft. 0 in.	Length producer room, includes bunkers, 15 ft. 0 in.
	Square feet producer room, 450
	Square feet per h.p., 0.45
Square feet boiler room, including bunkers, 900	Square feet producer room with four smaller generators, 330
Square feet per h.p., 0.9	Square feet per h.p., four generators, 0.33
Bunker capacity, 340,000 lb.	Bunker capacity, 160,000 lb.
Total weight, machinery and fuel, 692,000 lb.	Total weight, machinery and fuel, 347,000 lb.
Total length of machinery space including bunkers, 52 ft. 0 in.	Total length of machinery space, 34 ft. 6 in.
	Saving in weight, 355,000 lb.
	Saving in fore-and-aft length, 17 ft. 6 in.
	Saving in cubic space 17 ft. 6 in. by 32 ft. beam by 20 ft. high, 11,200 cu.ft.


Bunker, 170 Tons
Coaling Hatch 5 x 24"
Ash Ejector
Hold Stringer
Deck House
Deck House
Hold Stringer
Skylight 7" x 15"
100" Fan 66" Wheel
Duplex, Fire etc.
Duplex Ballast
Single Feed
Engine Hatch, Grated
12" Centrifugal Ballast
Tank Top at Side
Tank Top at Side
Working Platform
Working Platform
Dynamo Deck
15 K.W. Generator

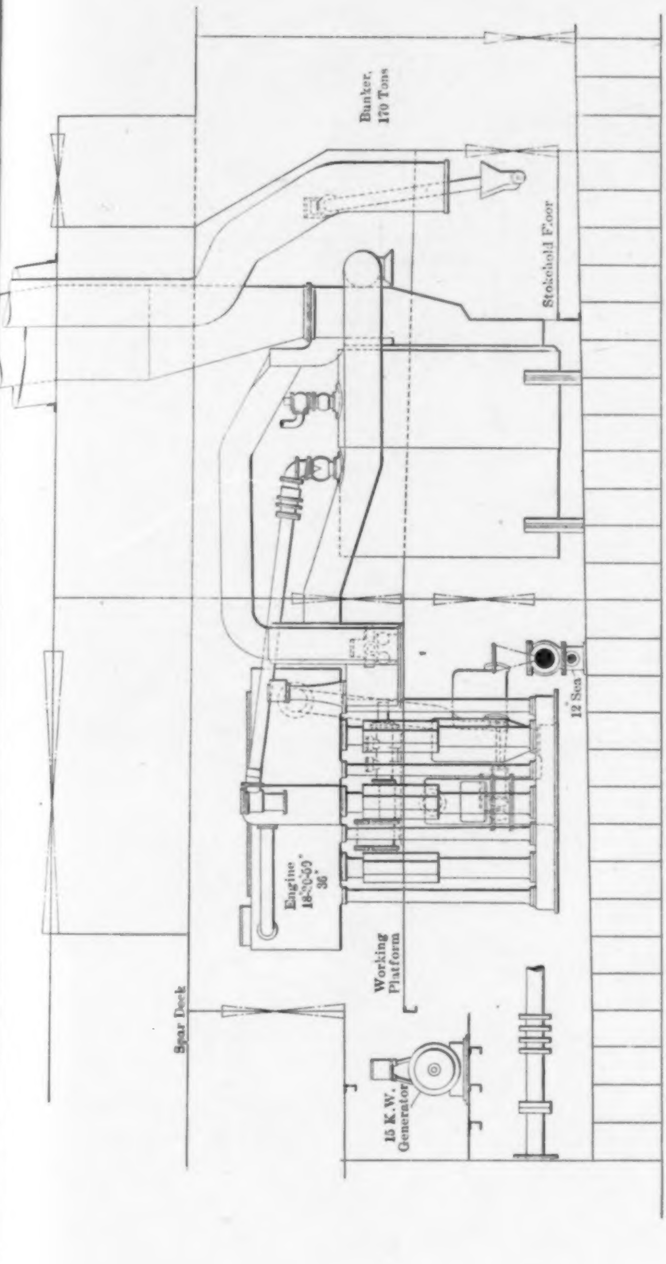
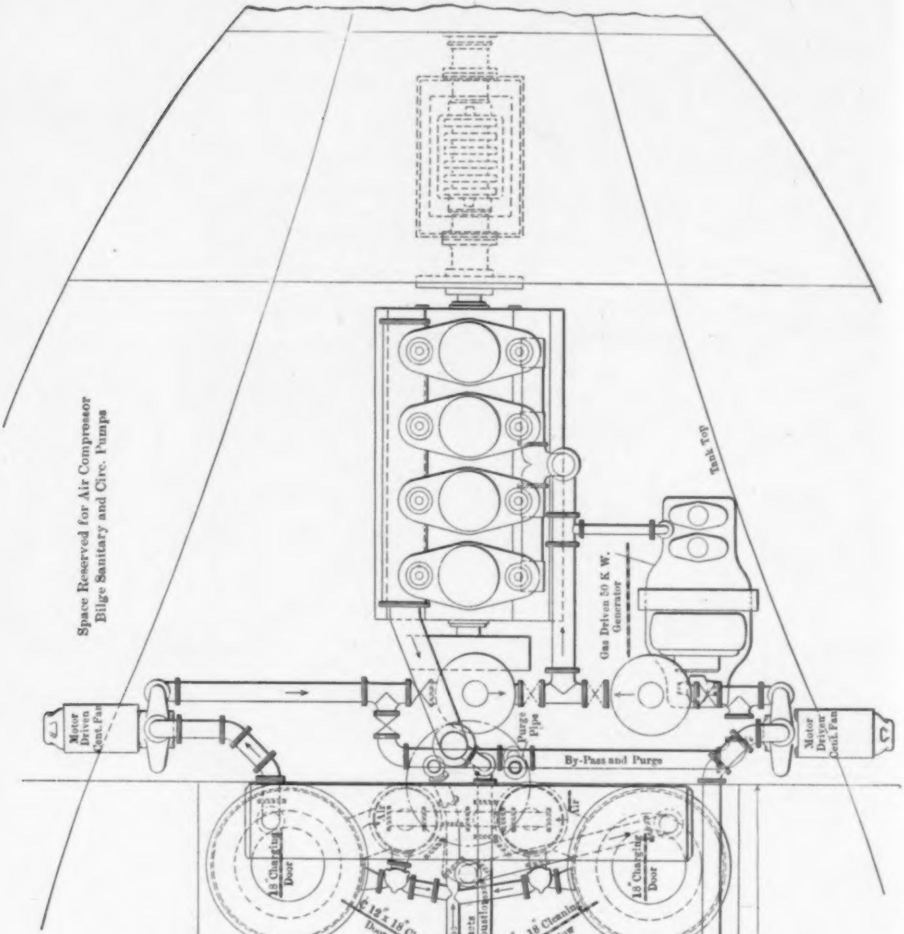


FIG. 1 PLAN AND ELEVATION OF 1000 H. P. STEAM POWER EQUIPMENT NOW INSTALLED IN LAKE FREIGHTER. TRIPLE-EXPANSION ENGINES; TWO SCOTCH BOILERS


Space Reserved for Air Compressor
Bilge Sanitary and Circ. Pumps
Tank Top
Gas Driven 50 K. W. Generator
Motor Driven Cent. Fan
Motor Driven Cent. Fan
Purge Pipe
By-Pass and Purge
18" Charging Door
18" Charging Door
18" Charging Door
18" Charging Door
12" x 18" Cleaning Door Below
12" x 18" Cleaning Door Below
12" x 18" Cleaning Door Below
12" x 18" Cleaning Door Below
Vent Pipe
Products of Combustion
Three-Way Valve
Air
Air
Air
Air
Coal
Coal
15'0"
21'10"

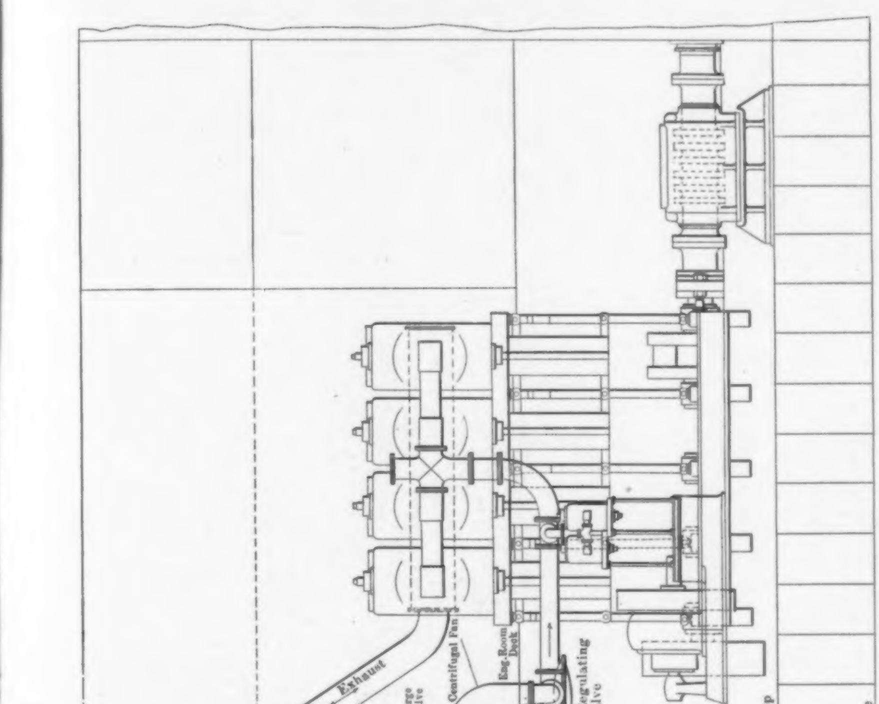
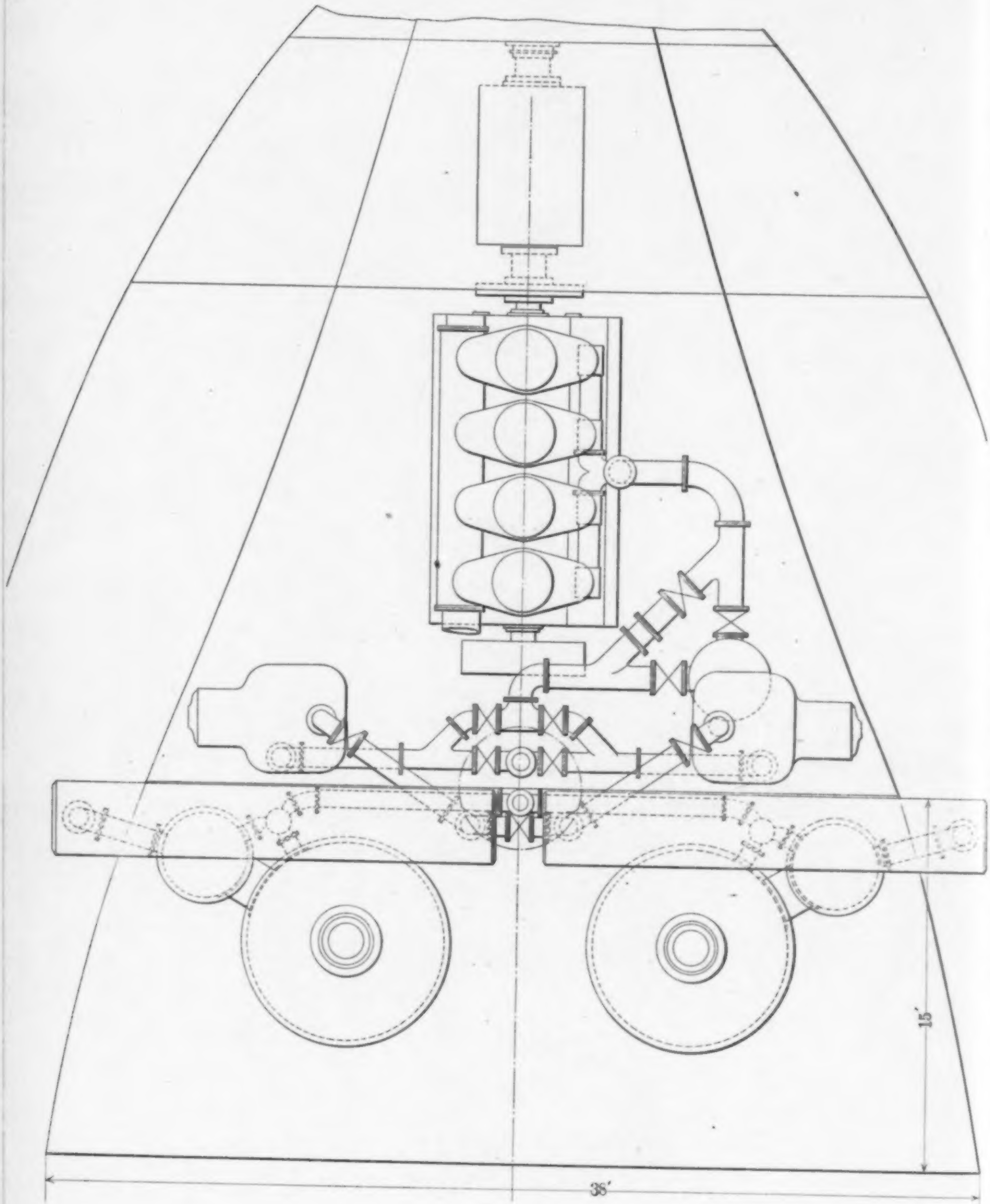


FIG. 2 PLAN AND ELEVATION OF PROPOSED FOUR-GENERATOR MARINE PRODUCER PLANT; 1000 H.P.



15'
38'

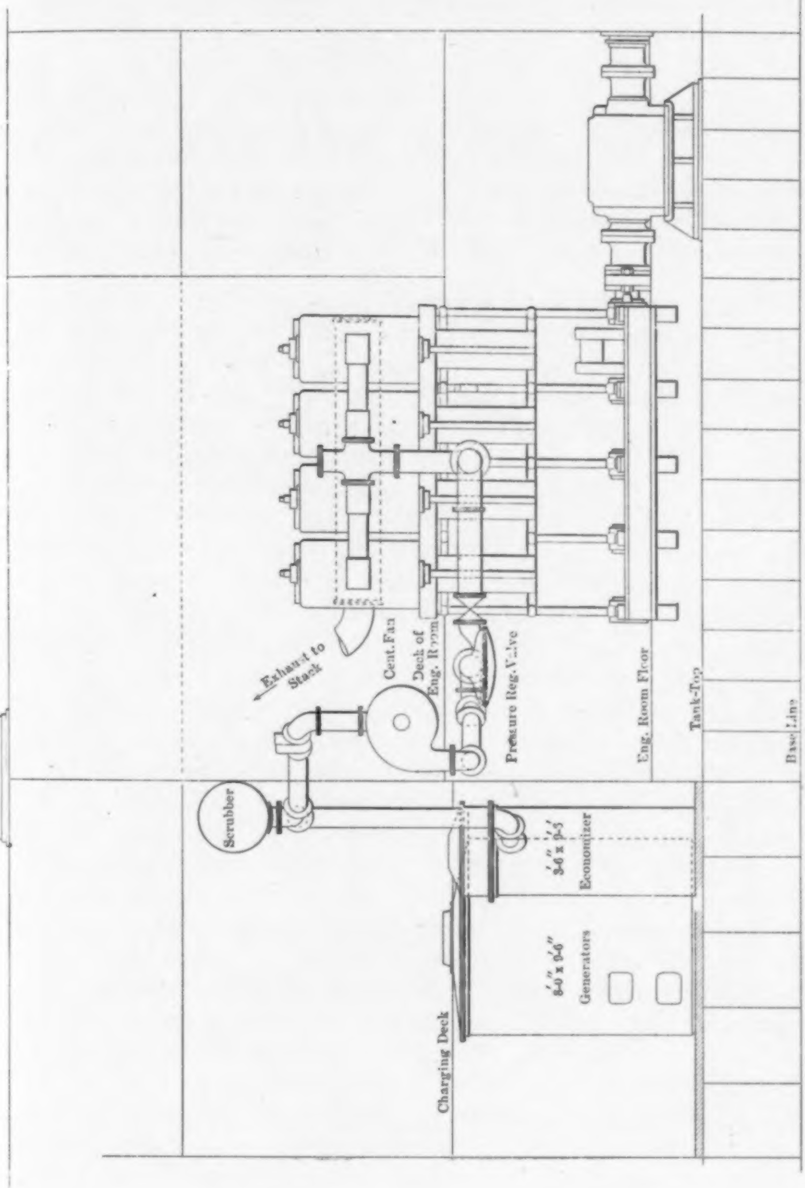


FIG. 3 PLAN AND ELEVATION OF PROPOSED TWO-GENERATOR MARINE PRODUCER PLANT; 1000 H.P.

and this comparison, while somewhat premature, is made to present the possibilities of marine producer gas power to those interested in its future.

33 A marine bituminous gas plant, similar in construction and operation to the one described, but of 300-h.p. capacity, has been in commercial operation driving a six-cylinder, single-acting, reversing marine gas engine for over a year. The results obtained give ample security for the statements made in this paper, and point to the early adoption of this type of prime mover for our marine commercial service.

A UNIQUE BELT CONVEYOR

By E. C. Soper, Detroit, Mich.
Member of the Society

It is quite possible that a descript'on of a belt conveyor a quarter of a mile long, and requiring more power to operate empty than loaded, will be interesting to some of the members and since its installation and operation are at variance from the prescribed rules of conveyor design, we beg to submit the following:

2 The belt conveyor was built during the summer of 1908 in one of the large portland cement plants of the South. It consists of a 24-in. 8-ply canvas belt in two sections, one section about 1000 ft. between centers, and the other with 1100 ft. between centers, its function being to convey the shale used in the manufacture of the cement, from the shale quarry to the plant. The shale deposit is located on a mountain about 247 ft. above the shale storage tanks, as shown in profile, Fig. 1. The two sections intersect at an angle of 140 deg. 40 min., so that the blasting from the limestone quarry does not interfere with the operation of the belt. The belt conveys the shale around the limestone quarry, as shown in plan, Fig. 1.

3 The belt is flat and carried by rollers, the top row having 4 ft. between centers and the return idlers 12 ft. between centers. Guide rollers are placed with about 40 ft. between centers along both upper and lower belts. (See Fig. 2.) The majority of manufacturers of belt conveyors recommend the maximum length between centers of a single belt to be about 700 ft. to 800 ft.

4 Referring to Fig. 1, the belt conveys the material down-hill, and to this fact is due the apparently parodoxical results in power required to operate, shown in Tables 1 and 2.

5 Because of the extreme length of the belt, and the fact that there is no roof or other covering, it was necessary to install some system for taking care of the expansion and contraction, in addition

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to the ordinary stretch of the belt, which is taken up in the majority of installations by 24-in., 36-in. or 48-in. takeups, according to length of belt. A set of 36-in. takeups, (Fig. 3) was installed at the upper end of each of these belts to maintain alignment and equal

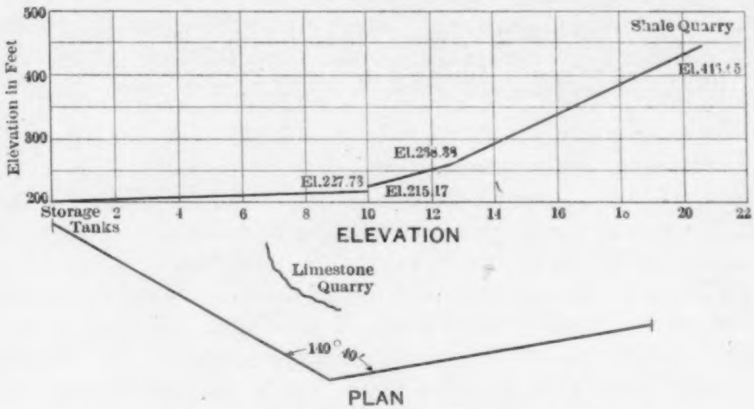

Fig. 1 Profile Showing Elevation and Plan of Conveyors

tension on each edge of the belt. The system installed acts as a tension carriage and makes it less often necessary to cut out the

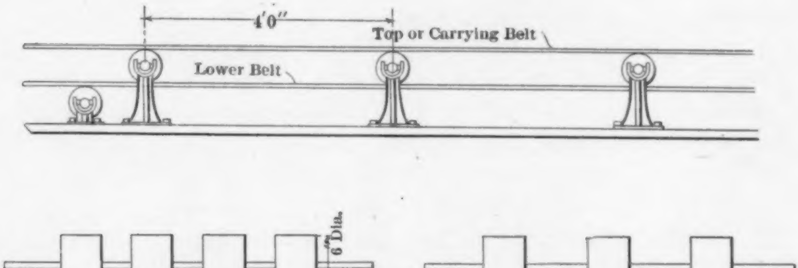

Fig. 2 Details of Forward and Return Idlers

slack in the belt, and in cool and wet weather the belt adjusts itself, the increased tension due to contraction raising the weight in the tower. A 10-h.p. motor drives each section. The lower section has a 6-ft. drop and requires approximately 5.1 h.p. to operate empty and 5.1 h.p.

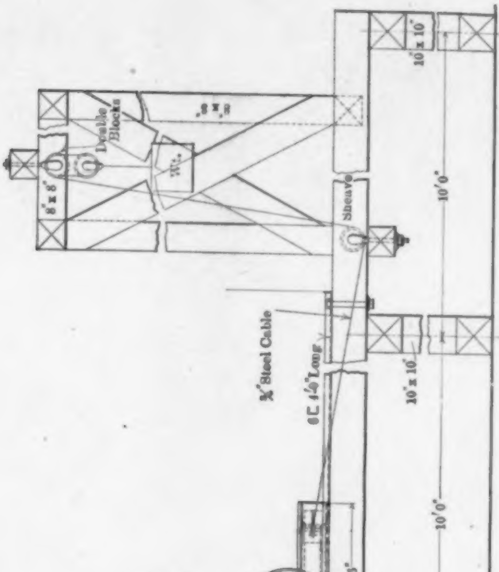

FIG. 3. DETAILS OF TAKE-UP ARRANGEMENT FOR BELTS

FIG. 4 VIEW OF DISCHARGE FROM UPPER TO LOWER SECTION

FIG. 5 LOOKING DOWN ON FIRST OR LOWER SECTION

FIG. 6 SIDE VIEW OF UPPER SECTION

to carry a load of 1200 lb., as shoveled by ten men. (See tests which follow.) The discharge from the upper to the lower sections through a chute is shown in Fig. 4. There is no spilling of material at any point of the travel, and pieces of shale a cubic foot in size are carried. The upper section is driven, contrary to practice, at the upper end, the pull being on the lower or slack side of the belt, but in this case, due to the pull of gravity on the top side, the belt was found to work better with the pull on the lower side.

Fig. 7 General View Showing Both Belts

6 The several halftones give views of the belt taken from different points. In clearing a way through the woods, the poles obtained were utilized for trestling and the planking was obtained from the scrap pile of concrete-form lumber.

7 Fig. 6 is a side view of the lower end of the upper section, showing the two depressions in the belt, and though these depressions do not conform closely to the prescribed radius of 300 ft., there is no lifting of the belt from the carrying idlers.

8 Power tests were made on the two sections after the belt had been operating a few days, with the following results: the speed of

the belt of the lower section, which has a grade of 2.4 per cent for 665 ft., or $0.024 \times 665 = 16$ ft., was 146 ft. per min.; the belt was driven by a 10-h.p. direct-current Westinghouse motor, and was loaded 2.2 lb. per ft. for a distance of 550 ft., or 1210 lb.; this load fell 16 ft. in 5 min. Then

$$\frac{1210 \times 16}{5} = 3520 \text{ ft.-lb. of work exerted by load}$$

or,

$$\frac{3520}{33{,}000} = \frac{1}{11} \text{ h.p. (approx.) helping to pull the belt.}$$

When the belt was loaded as above, a test of the motor showed that 16 amperes, 239 volts, or 5.1 h.p., were required. There was no appreciable difference in the ammeter and voltmeter readings, when belt was empty or loaded, as in test.

9 When the belts were installed, after trying them out and ascertaining how easily they could be operated, a sprocket was placed on the tail-shaft of the lower section and also one on the head-shaft of the upper section, and the two sprockets were connected by a vertical quarter-twist chain. The idea was to drive both belts by a 10-h.p. motor at the head of the lower belt section, after all shafts had become well seated in the bearings and the stiffness had disappeared from the belt and it was in good operating condition. This was also necessary in order to take up the slack in the upper section when starting, and *the speeds were such that the top side of the belt ran 3 ft. per min. faster than the lower side.* The results of a series of tests are given in Tables 1 and 2.

TABLE 1 POWER TESTS OF BELTS UNDER CONDITIONS NOTED IN TEXT

Time (A.M.)	Volts	Amperes	Watts	H.P.	Notes
9:50	207	12	2484	3.3	Belts chained together
10:08	210	12	2520	3.3	Eight men loading
10:09	208	14	2912	3.9	Connecting chain off, 10-h.p.
10:11	210	14	2940	3.9	motor only
10:15	200	14	2800	3.7	Gradual increase in electrical load
10:20	200	15	3000	4.0	due to decrease in shale load
10:35	200	16	3200	4.2	

NOTE: Low voltage due to very small mains and long distance (2500 ft.).

TABLE 2 SECOND SERIES OF TESTS

Time (P.M.)	Volts	Amperes	Watts	H.P.	Notes
2:00	194	16	3104	4.1	Empty. Connected to lower belt by chain
2:15	180	16	2886	3.8	All readings at motor and not including line loss
2:25	182	18	3275	4.4	
2:35	186	18	3348	4.4	
3:45	195	14	2730	3.6	Loaded by seven men
3:50	185	19	3515	4.7	Loaded as before, but with connecting chain off. 10-h.p. motor only

Note: Readings taken on motor at upper end of upper belt-section.

Initial and Operating Costs

10 Tables are given herewith upon the first cost of the equipment (Table 3) and the cost of operation and maintenance (Table 4). Table 4 is based upon a capacity of 200 tons conveyed in ten hours. Inasmuch as the capacity is directly proportional to the speed, if it was desired to increase the capacity of the conveyor, it would only be necessary to increase the travel of the belt per minute, and from experience, it is quite possible that by doubling the load the power required to operate would be reduced 50 per cent.

11 The operation costs given in Table 4 are taken from actual practice. Doubling the capacity per day and assuming above costs to be approximately the same reduces the actual cost of conveying to $0.0038 per ton. Interest and depreciation, $0.0063, or a total of $0.0101.

TABLE 3 COST PER FOOT OF COMPLETED BELTS INCLUDING ELECTRICAL MOTORS, TRESTLING, ETC.

Materials	Total Cost	Cost per Ft.
Lumber	$ 496.34	$0.238
Belt	5361.52	2.58
Castings	1435.77	0.69
Electrical equipment, including two 10-h.p. motors	637.11	0.316
Miscellaneous: nails, bolts, screws, iron, etc	193.20	0.093
Labor	962.20	0.46
	$9106.16	$4.37

Note: Length of first section, center to center, 998 ft.; second section, 1082 ft.; total, 2080 ft.; takeup, 15 ft.

Cost of castings includes machine work, etc.

12 Regarding the operation of the belt: after the stiffness had disappeared there was very little slipping at the head or drive pulleys, and there was sufficient lubrication in the shale itself to form a waterproof covering about $\frac{1}{8}$-in. thick on the belt, thereby protecting it not only from wear but from the action of the elements, and proving a very good dressing to keep the belt pliable. Because of the slow speed, etc., there are very few repairs necessary to the belt, and in this instance, being coated as described above, the belt should last several years.

TABLE 4 COST TO OPERATE AND MAINTAIN BELT CONVEYOR

		PER 10 HR. DAY	PER TON
Power			
10 h.p. at $0.004 per h.p.-hr		$0.40	$0.002
Labor			
Boy oiling, etc	$0.75		
Taking up slack once in 7 days, 2 men, 3 hr. at $0.20 per hr	0.171	0.92	0.0046
Supplies			
Belt Lacing	0.10		
Waste, Resin, etc	0.10	0.20	0.001
Total		$1.52	$0.0076
Oil (no charge, using waste oil from large crushers).			
Interest, etc.			
Interest, Depreciation, Renewals, 10 per cent on investment of $9200		2.52	0.0126
Grand Total		$4.04	$0.0202

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VERSUCHE ZUR ERMITTLUNG DES KRAFTBEDARFS AN WALZWERKEN. By J. Puppe. *Düsseldorf, 1909.* Gift of the Verein Deutscher Eisenhüttenleute.

WATER POWER ENGINEERING. By D. W. Mead. *New York, McGraw Publishing Co., 1908.* Gift of publishers.

WORLD ALMANAC AND ENCYCLOPEDIA, 1909. *New York, Press Publishing Co., 1909.* Purchase. $0.25.

GIFT OF ISAAC C. GREEN

ALLEGEMEINE MASCHINENLEHRE. By Dr. Moritz Rühlmann. 2d edition. 4 vol. *Braunschweig, C. A. Schwetschke & Sohn, 1875.*

DER DAMPFMASCHINEN-CONSTRUCTEUR. By H. von Reiche. 1st edition. 2 vol, comprising text and atlas. *Aachen, J. A. Mayer, 1880.*

ÜBER DAMPFMASCHINEN MIT HOHER KOLBENGESCHWINDIGKEIT. By Johann Friedrich Radinger. 2d edition. *Wien, Carl Gerolds Sohn, 1872.*

DAMPFMASCHINEN UND TRANSMISSIONEN IN DEN VEREINIGTEN STAATEN VON NORD-AMERIKA. By J. F. Radinger. 1st edition. *Wien, Faesz & Frick, 1878.*

DESCRIPTION OF A CARGO-CARRYING COASTING STEAMSHIP, WITH DETAILED INVESTIGATION AS TO ITS EFFICIENCY. By Lindsay Burnet. 1st edition. *London, Institution of Civil Engineers, 1881.*

JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS. Vol. 1, no. 3, August 1889. *Washington, R. Beresford, 1889.*

DER LOCOMOTIVBAU IN DEN VEREINIGTEN STAATEN VON NORD-AMERIKA. By Alois von Feyrer. 1st edition. *Wien, Faesz & Frick, 1877.*

DIE MOTOREN. By J. F. Radinger. 1st edition. *Wien, K. & K. Hof- und Staatsdrückerei, 1874.*

REVIEW ON THE PROGRESS OF STEAM SHIPPING DURING THE LAST QUARTER of A CENTURY. By Alfred Holt. With abstract of discussion. Edited by James Forrest. 1st edition. *London, Institution of Civil Engineers, 1878.*

Steam Ship Capability, Power, Consumption of Fuel, Cargo Capacity. By Thomas Wingate. 1st edition. *Glasgow, A. & W. MacTear.*

Triple Expansion Engines, Cylinder Proportion, Power, Fire Grate, and Heating Surface of Boilers. By Thomas Wingate. 1st edition. *Glasgow, A. & W. MacTear.*

Vorträge über Geschichte der theoritischen Maschinenlehre und der damit in Zusammenhang stehenden mathematischen Wissenschaften. By Dr. Moritz Rühlmann. 1st edition. 3 vol. *Braunschweig, C. A. Schwetschke & Sohn, 1881.*

EXCHANGES

American Society of Civil Engineers. *Transactions.* Vol. 62. *New York, 1909.*

Annales des Ponts et Chaussées. Vol. 6, no. 36-date. *Paris, 1909.*

Cenozoic Mammal Horizons of Western North America. (U. S. Geological Survey, Bulletin no. 361.) By H. F. Osborn. *Washington, Government, 1909.*

Economic Geology of the Georgetown Quadrangle, Colorado. (U. S. Geological Survey, Professional Paper no. 63.) By J. E. Spurr and G. H. Garrey. *Washington, Government, 1908.*

Geology and Mineral Resources of the Laramie Basin, Wyoming. A Preliminary Report. (U. S. Geological Survey, Bulletin no. 364.) By N. H. Darton and C. E. Siebenthal. *Washington, Government, 1909.*

Geology and Water Resources of the Great Falls Region, Montana. (U. S. Geological Survey, Water Supply Paper no. 221.) By C. A. Fisher. *Washington, Government, 1909.*

Glaciation of the Uinta and Wasatch Mountains. (U. S. Geological Survey, Professional Paper no. 61.) By W. W. Atwood. *Washington, Government, 1909.*

L'Ingegneria Ferroviaria. Year 6-date. *Roma, 1909*-date.

Interpretation of Topographic Maps. (U. S. Geological Survey, Professional Paper no. 60.) By R. D. Salisbury and W. W. Atwood. *Washington, Government, 1908.*

Mineral Resources of the United States, 1907. Parts 1–2. *Washington, Government, 1908.*

Nouvelles Annales de la Construction. Vol. 6, no. 649-date. *Liege, 1909.*

Pollution of Streams by Sulphite Pulp Waste. A study of possible remedies. (U. S. Geological Survey, Water Supply Paper no. 226.) By E. B. Phelps. *Washington, Government, 1909.*

PORTEFEUILLE ECONOMIQUE DES MACHINES. Vol. 7, no. 637-date. *Liege, 1909.*

SIGNIFICANCE OF DRAFTS IN STEAM BOILER PRACTICE. (U. S. Geological Survey, Bulletin no. 367.) By W. T. Ray and Henry Kreisinger. *Washington, Government, 1909.*

CATALOGUES

ALBERGER PUMP COMPANY, *95 Liberty Street, New York, September 1908.* Catalogue B. Volute Centrifugal Pumps.

AMERICAN BLOWER COMPANY, *Detroit, Mich.* Shop Heating. A Treatise Containing Practical Suggestions. By F. R. Still. *1908.*

AMERICAN BRASS MANUFACTURERS. Price List no. 7.

CONTINENTAL IRON WORKS, *Brooklyn, N. Y.*

Catalogue for 1908. 7th edition. Photographs and descriptions of internal furnace tubular boilers with Morrison suspension furnaces of all styles; tables showing rating of power of boilers; sectional drawings and designs of boilers ranging from 50 h.p. to 300 h.p.; testimonials as to efficiency of boilers where used.

DU BOIS IRON WORKS, *Du Bois, Pa.* Motor, Gasoline Engine and Belt Driven Pumps. Bulletin EP, no. 3.

FAIRBANKS, MORSE & CO., *Chicago, Ill.* Bulletin no. 21, Standard "TR" Type D. C. Dynamos and Motors; Bulletin no. 23, Standard "E" D. C. Dynamos and Motors; Bulletin no. 26, Fairbanks, Morse Special Motors; Supplement, Back Geared Motors; Bulletin no. 32, Direct Connected Exhaust Fans; Bulletin no. 38, Engine Type Generators; Bulletin no. 204, A. C. "B" Type Induction Motors; Bulletin no. 205, A. C. "B" Type Generators; Bulletin no. 206, A. C. Engine Type Generators; Bulletin no. 207, A. C. Induction Motors, Types BH and BV. Catalogues, no. 44D, Horizontal Engines; no. 45C, Hoists; no. 47C, Pumping Machinery; no. 48D, Steam Pumps.

HOOVEN, OWENS, RENTSCHLER COMPANY, *Hamilton, Ohio.* Type H. S. High Speed Corliss. Bulletin no. 104.

JEFFREY MANUFACTURING CO., *Columbus, O.* Catalogue no. 32A.

Coal and ashes handling machinery for power plants, and places where machinery has been successfully used.

CHAS. C. MOORE & COMPANY, *San Francisco, Cal.* A Modern Steam Power. Central Station.

NATIONAL MACHINERY COMPANY, Tiffin, Ohio. Catalogue E.

Bolt, nut and rivet machinery, upsetting and forging machines, and wire nail machines. Tables showing dimensions of manufacturers' standard bolts, heads, nuts.

NELSON VALVE COMPANY, *Wyndmoor, Philadelphia, Pa.* Catalogue. *1909.*

NILES-BEMENT-POND COMPANY, *New York.* Bement Hammers.

Northwestern Expanded Metal Company, *930 Old Colony Bldg., Chicago, Ill.* Expanded Metal Information, Concrete and Steel. *1908.*

Pratt and Whitney Company, *Hartford, Conn.* Gages and Standards.

Randolph-Clowes Company, *Waterbury, Conn.*

Seamless drawn brass and copper tubing, tanks and shells, brazed tubes, moldings, sheet brass and brass rods, Brown & Bros. seamless drawn copper range boilers.

Scully Steel & Iron Co., *Halstead and Fulton Sts., Chicago, Ill., March 1909.* Stock list of steel and iron goods with dimensions and stock prices.

Termaat & Monahan Co., *Oshkosh, Wis.*

Catalogue, showing detail construction and explanation of two, three, and four-cylinder reversible, T. & M. marine engines.

Hubert H. Ward and Associates, *Cleveland, O.*

Seaton spring wheel, suitable for automobiles, trucks, and railway cars; full description of principle, construction and advantages.

Ward Leonard Electric Co., Bronxville, N. Y.

Motor Starters, equipped with tightcasings enclosing all current-carrying parts, for automatically starting motor, and accelerating to full speed, or restoring rheostat lever to starting position in case of interruption of current supply.

Westinghouse Electric and Manufacturing Company, *Pittsburg, Pa.* Luminous Radiators and Air Heaters, Folder 4120, *Feb. 1909.* Direct Current Electric Fans, Folders 4100, 4101, *Jan.* 1909. Battery Charging Methods, Folder 4134, *March 1909.* Electric Sad Iron, Folder 4098, *Feb. 1909.* Multiple Tungsten Lamps for Alternating or Direct Current Circuits, Circular no. 1160.

COMMENT ON CURRENT BOOKS

THE STEAM TURBINE. A Practical and Theoretical Treatise for Engineers and Designers, including a discussion of the gas turbine. By James Ambrose Moyer, S.B., A.M., *John Wiley & Sons. New York.* 1908. Cloth, 8vo. ix + 370 p., 225 figures. Price, $4 net.

Professor Moyer has had an extended experience in experimental work incident to the manufacture of steam turbines, and also as an instructor in engineering. He has aimed in this treatise to explain some of the more important problems connected with steam turbines. Two chapters of unusual interest to the designing engineer are upon nozzle design and blade design. Nozzles are becoming an important element in all types of turbines and many conditions affecting their efficiency are now well established. Illustrative examples are worked out in these two chapters and to supplement the calculations upon blade design in which allowance must be made for mechanical losses, a discussion of these losses is given, with an estimate of their probable magnitude. The chapter upon turbine tests is meager, but with it must be considered two other chapters, one upon turbine economy, and one upon methods for correcting turbine tests. Under turbine economics are discussed the influence upon economy of steam pressure vacuum, superheated steam, etc., together with operative and initial costs, plant design and operation, etc. A chapter relates to corrections that must be made to compensate for different conditions under which tests are made, with a view to bringing results to a standard basis for comparison. There is a chapter on stresses in rotating rings, drums and disks, a brief discussion on gas turbines, and by way of introduction a very clear treatment of the elementary theory of heat, with special reference to the temperature-entropy diagram as applied to turbine operations. There is a comprehensive description of commercial types, including low-pressure turbines. The marine turbine receives but a brief treatment in a very short chapter.

Contents by chapter headings: Introduction; The elementary Theory of Heat; Nozzle Design; Steam Turbine Types and Blade Design; Mechanical Losses in Turbines; Method for Correcting Steam Turbine Tests; Commercial types of Turbines, De Laval, Parsons, Westinghouse, Allis-Chalmers, Curtis, Rateau, Wilkinson, Zoelly, Sturtevant, Riedler-Stumpf, Kerr, Terry, Dake, etc.; Governing Steam Turbines; Low Pressure (exhaust) Turbines; Marine Turbines; Steam Turbine Economics; Stresses in Rings, Drums, and Disks, Design of Turbine Wheels, Critical Speeds of Loaded Shafts; Gas Turbines; Electric Generators for Turbines, Direct-Current Generators, Alternating-Current Generators.

A POCKET BOOK OF MECHANICAL ENGINEERING. Tables. Data, Formulae, Theory and Examples. For Engineers and Sudents. By Charles M. Sames, B.Sc. *Jersey City, N. J.* 1908. Third edition, revised and enlarged. Pocket size, leather, vii + 195 p. Price $2.

A pocket-book in reality as well as in name is this little reference work of mechanical engineering, now in its third edition. The table of contents shows its scope.

The effort has been to cull out from engineering data the formulae, tabular matter and other information usually required by mechanical engineers and students, and having for an aim the presentation of the material in an exceedingly condensed form without duplication of data, with a view to making the book compact. In the third edition new matter has been added upon reinforced concrete, high-speed tool steel, superheated steam and journal friction. It is printed in small type on thin paper, with flexible leather covers, after the usual style of the better class of pocket-books.

Contents, by chapter headings: Mathematics, Chemical Data; Materials; The Strength of Materials, Structures, and Machine Parts; Energy and the Transmission of Power; Heat and the Steam Engine; Hydraulics and Hydraulic Machinery; Shop Data; Electrotechnics; Appendix.

ACCURATE TOOL WORK. By C. L. Goodrich and F. S. Stanley. *Hill Publishing Company, New York.* 1908. Cloth, 6 by 9, 217 p., 221 illustrations. Price, $2 net.

The development of accurate processes in the manufacture of tools and machine parts has extended to nearly every branch of machine manufacture and refinements in methods are to be found in almost all tool rooms. Many of these methods originated in watch factories and similar establishments, but they have been found applicable in producing work of different character and heavier proportions. This book treats of these methods, dealing with the use of master plate, disc, button and test indicator processes, the use of the microscope in connection with micrometer measurements and other ingenious processes, and methods of measuring tapers and angular work. Mr. Goodrich, department foreman with the Pratt & Whitney Co., Hartford, Conn., has had long experience in work of this kind, and Mr. Stanley, associate editor of the American Machinist, is a practical tool maker. Much of the material has been contributed by the authors or by others to the columns of the American Machinist. The book is handsomely illustrated, both by diagrams and half-tone engravings from photographs of actual work. It places on record in convenient form much needed information upon modern shop methods of accomplishing the most accurate results possible in machine work.

Contents by chapter headings: Locating and Boring Holes in Drill Jigs; Locating and Boring Oblique Holes in Jigs; Economical Jig Work on the Milling Machine; Boring Holes on the Miller and Checking with Verniers: A Precision Drilling and Reaming Machine; Master Plates and How They are Made; Master Plates and Their Uses in Die Making; Master Plates Used in Making Watch Tools; Trigonometry in the Tool Room; A Tool for Laying Out Angles; Measuring Dovetail Slides, Gibs and V's; A Gage for Producing Accurate Tapers; The Microscope in the Tool Room; The Microscope in the Manufacturing Plant; Making a Set of Accurate Index Dials; Inspecting Tools with the Test Indicator; A Universal Indicator and Some of Its Applications; A New Swedish Combination Gaging System; Setting, Laying Out and Testing Work with the Swedish Gages.

THE ECONOMY FACTOR IN STEAM-POWER PLANTS. By George W. Hawkins. *Hill Publishing Company, New York.* 1908. Cloth, 6 by 9. 133 p., 50 figures. Price $3 net.

The author has presented a discussion with ample data upon the economical design and operation of steam power plants. It is only consideration of the economy of each of the elements of a plant that leads to a high plant efficiency, and the author, therefore, properly introduces the subject by a chapter on individ-

ual apparatus. In this are considered the economy of several leading types of engines and of turbines, with a review of controlling factors in condensing apparatus, feed water heaters, economizers, etc. Diagrams have been plotted giving the steam economy of engines of different types and sizes when operating under different loads. Data are given upon steam or power required for circulating pumps, air pumps, feed pumps, etc. A comprehensive chapter treats of plant economy as a whole, with many diagrams and tables and calculations carried through for different arrangements of apparatus and plans of operation. These relate to non-condensing, surface condensing and jet condensing plants, with auxiliaries direct-connected and belted; and with auxiliaries steam-driven and motor-driven. Conclusions derived by the author's methods will prove illuminating and valuable to those who have to predetermine the results from various types of power plants under certain conditions; he discusses variable loads which have so important a bearing on the economy of practically all power plants. There are also diagrams and tables for reducing the performance of a boiler to the standard basis of "from and at 212 deg." taking into account the feed water temperature and steam pressure. The author has based his book upon the use of fuel oil and has supplied conversion charts to afford ready means of converting the heat elements of oil to those of coal or wood.

Contents by chapter headings: Introduction. Part I. Individual Apparatus; Boilers; Engines; Electrical Generators; Condensing Apparatus; Feed-Pumps; Oil-Pumps; Oil-Burners, Radiation, Leakage; Feed-Water Heaters; Fuel Economizers. Part II. The Factor of Evaporation. Part III. Complete Plant Economy: Introductory; Non-Condensing Plants; Surface-Condensing Plants; Jet-Condensing Plants; Pumping Plants; Examples. Part IV. Complete Plant Economy: Phases of the Problem; Method of Solution. Conclusion.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 15th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

058 Construction work—reinforced concrete bungalows and cottages—organization in need of an engineer having had varied experience in reinforced concrete, experienced in calculating strains and stresses and proportioning members for load and weight; plan is by pilaster or palisade with thin curtain walls. Location Pennsylvania.

059 Man of wide experience in manufacture of automobiles, as general foreman. Location Rhode Island.

060 Well-equipped machine shop with equipment to run about twenty-five men; present owner wishes to devote time to certain patents and desires someone to take charge of present shop; will finance the proposition if necessary or form small stock company giving the proper party full charge. Location Maryland.

061 Shop superintendent, energetic, good systematizer with thorough experience in building steam engines and medium explosion engines, also pumps or compressors, if possible. Must be competent to determine the most economical methods of machining any given piece and be familiar with the whole of modern shop practice.

062 Wanted: prominent engineer of wide experience as specialist in ice-making machinery.

063 Manager of an iron works employing 50 to 75 men, doing general foundry and machine work as is usual in connection with mining, smelting and concentrating machinery. Man of good business ability and training as well as having general engineering experience essential. Location Montana.

064 Superintendent of one of the largest machine-tool concerns in the United States wants young man who can grow up in the establishment, and finally take superintendent's position. Preferably not over thirty years old. Must have had a varied and practical experience on engineering matters outside of the ma-

chine-tool lines. Must speak English and some German. Should have University education, executive ability, and good address. If you are the man I am looking for, write Superintendent, Box 143, American Machinist.

065 Wanted—high grade foundry superintendent for machine-molding grey iron foundry; building and equipment new and up-to-date. Present daily capacity, 35 tons. A splendid opportunity for an advanced practical foundryman; exemplary character, good habits and executive ability essential. State full particulars, present salary, and references. Address, Superintendent, Box 143, American Machinist.

066 Reliable machinery salesman to travel in Spanish-speaking countries. Must be especially competent. Knowledge of Spanish a requisite.

MEN AVAILABLE

239 Assistant engineer of one of largest automobile plants. Eight years automobile experience in France and the United States. Commercial wagon work a specialty. Desires position as chief or assistant engineer in motor car works, preferably on business vehicles.

240 Member, civil and mechanical engineer, twenty-five years experience in general engineering, and eighteen years as specialist in dredging machinery and hydraulic dredges. Holds all world's records for hydraulic dredge performance, including best records on new Erie Canal. Will take entire charge of such department with large contracting firm.

241 Engineer, thirty years old, technical graduate, desires position as works manager, superintendent, or mechanical engineer with a moderate sized progressive concern. Shop and drafting work, devising and installing cost, shop and production systems, also experienced in electrical installations for industrial plants.

242 Junior member, forceful, wide-awake manager, of proven executive ability. Experience covers railroad shops, both locomotive and car, designing in drafting-room, and actual operation of a mainline division, selling and installing general machinery and gas-power plants, also allied railroad supplies. M. I. T. graduate; worked-up from shop apprentice, has successfully installed piece-work, bonus and cost systems, and is familiar with methods of bettering production. Can plan and carry out a business campaign. Unusual talent for organizing.

243 Member, of thorough mechanical and business training, good executive and organizer; at present employed as manager. Patentee many devices. Wishes to make a change.

244 Member, teacher in technical college, eight years experience in steel-mill, rolling-mill and bridge-shop designing, desires employment in the above or similar lines for three to four months, beginning about June 1, 1909.

245 Position as dean or director of a college of mechanical and electrical engineering, or head of a department in a large engineering school, by well-known

engineer actively engaged in mechanical engineering for ten years; present position dean of the college of mechanical and electrical engineering in one of our well-known universities, for the past eight years. Can furnish the best of references, including the administration and officers of this university. Only responsible position with bright future can be considered. Record is open to inspection by institution having the right kind of position to offer.

246 Position desired, by a member who has had a wide and varied experience in manufacturing and engineering, now qualifying under State Board of Law Examiners; wishes to engage in law office or with corporation requiring a legal and mechanical expert.

247 Junior, technical graduate, at present located in Middle West, desires position with engineering or manufacturing concern in New York City or Connecticut. Experienced in machine design and manufacture; position as assistant superintendent or chief draftsman preferred.

248 Engineer and superintendent, fifteen years experience in machine shop, engineering construction and design. Familiar with both Taylor and ordinary systems of management. At present in charge under a modification of the Taylor system. Competent and tactful, experienced in the installation of premium system and shop-betterment work.

249 Junior, desires position with engineering concern; seven years experience in engineering, has had charge of drafting room and erection. Familiar with modern office methods and books. Understands buying machinery, etc. At present assistant manager and assistant treasurer of an engineering concern. Prefers to locate in the vicinity of New York.

250 Member, long experience in pumping machinery, air compressors, Corliss engines, condensing apparatus; desires position as chief engineer or chief draftsman in neighborhood of New York City.

251 Stevens graduate wishes to become connected with department of experimental engineering. Broad practical experience.

252 Associate, age 32, experienced as inspecting mechanical and electrical engineer, desires similar position.

253 Mechanical graduate, general mechanical, electrical and construction experience, knowledge of engineering materials and contract practice, wishes position as assistant or executive in charge contract business.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Edward M. (1902), Ch. Engr., Quaker Oats Co., and *for mail*, 83 Charlotte St., Akron, O.

BACON, John Lord (Junior, 1899), Engr. and Supt. of Constr., R. P. Shields & Son, 605 Scripps Bldg., and *for mail*, 3435 D St., San Diego, Cal.

BAEHR, William Alfred (1903), 1943 Commercial Natl. Bank Bldg., Chicago, Ill.

BAILEY, Ervin G. (Junior, 1903), Mech. Engr., Fuel Testing Co., 220 Devonshire St., Boston, and 1057 Walnut St., Newton Highlands, Mass.

BECHTEL, John Adams (Associate, 1900), Williamsburg P. O., Va.

BIGELOW, Myron J. (1904), Mech. Engr., Molyneux Mailing Mchs. Co., 253 Ellicott St., and *for mail*, 357 Delaware Ave., Buffalo, N. Y.

BLOOMBERG, Jonas H. (1903), Cons. Engr., Avenida Del Cinco De Mayo No. 32, and *for mail*, Primera de Orizaba No. 11, Mexico City, D. F., Mexico.

BROWN, J. Linwood (1902), M. E., R. F. D. No. 1, Conneaut, Ashtabula Co., O.

CARLE, Nathaniel A. (1907), Box 32, Auraria, Ga.

CRANE, Edward S. (Associate, 1901), 3203 W. 14th St., Cleveland, O.

DAVIS, Chester B. (1890), 3353 6th Ave., Troy, N. Y.

FISHER, Henry Donald (Junior, 1907), Supervising Engr., U. S. Glass Co., Factory K, 18th and Merriman Ave., South Side, Pittsburg, Pa.

FOSTER, Ernest Howard (1885; 1894), Mech. Engr., V. P., Power Specialty Co., 111 Broadway, New York, N. Y.

FRANKS, Fredk. Benjamin (1904), 129 North West St., Allentown, Pa.

GOBEILLE, Jos. Léon (1886), Gobeille-Harris Pattern Co., Niagara Falls, N. Y.

GREEN, Samuel M. (1890), Cons. Engr., Hitchcock Bldg., 318 Main St., and 325 Long Hill St., Springfield, Mass.

GREENE, Harris Ray (Associate, 1907), Sales Engr., Alberger Condenser Co., 95 Liberty St., New York, N. Y., and 1406 Chapel St., New Haven, Conn.

GREENE, Isaac Chase (1882; 1886), Life Member, 29 W. 39th St., New York, N. Y.

GUELBAUM, David (1894; 1905), M. E., P. O. Box 293, Syracuse, N. Y.

HADDOCK, Edwin Jos. (1906), Mech. Engr., Schultz Bldg., Columbus, O.

HALL, Robert E. (1898; 1905), Asst. to V. P., Francis Bros. & Jellett, Inc., and *for mail*, 7802 Lincoln Drive, St. Martins, Philadelphia, Pa.

HARLAN, Orla K. (Junior, 1904), Dept. of Engrg. and Constr., Culebra, Canal Zone, Panama.

HELVEY, Geo. Stanley (Junior, 1904), 303 N. 2d St., Hamilton, O.

HODGE, Geo. O. (Junior, 1904), The Bristol Engrg. Corp., Bristol, Conn.

HUTCHISON, Arthur H. (1899), The C. W. Keltening Mercantile Co., 1617 Magee St., Denver, Colo.

JONES, Edward H. (1889), Clearwater, Fla.

KEITH, Thomas M. (Junior, 1905), Ch. Engr., Link Chain Belt Co., 52 Dey St., New York, and *for mail*, 241 Clinton Pl., Brooklyn, N. Y.

KENT, Robert Thurston (Junior, 1905), Managing Editor, Industrial Engineering, Empire Bldg., Pittsburg, Pa.

KLAHR, Charles Dean (Junior, 1905), Clarion, Pa.

KOON, Sidney Graves (Junior, 1905), The Hartford, Atwood St., Pittsburg, Pa.

LARDNER, Henry A. (1901), Mgr., J. G. White & Co. Inc., Alaska-Commercial Bldg., San Francisco, Cal.

LEMOINE, L. R. (Associate, 1887), Genl. Mgr., N. J. Zinc Co., 55 Wall St., and 161 Madison Ave., New York, N. Y., and 323 S. 18th St., Philadelphia, Pa.

MATTON, Fred V. (1892), Mech. Engr., Camden Iron Wks., Camden, N. J.

MERKT, Gustav A. (Associate, 1908), Designing Engr., Am. Steel and Wire Co., and *for mail*, 8 Blair St., Worcester, Mass.

MILLER, Frank Louis (Associate, 1907), 304 Everhart St., Johnstown, Pa.

MILLER, Fred J. (1890), Engineers' Club, 32 W. 40th St., New York, N. Y.

MURRAY, Arthur F. (Junior, 1908), Geo. F. Blake Mfg. Co., East Cambridge, Mass.

ORD, Henry C. (1905), Genl. Elec. Co., and *for mail*, 174 S. Common St., Lynn, Mass.

PITKIN, Joseph Lovell (Associate, 1903), Southern Rep., A. Klipstein & Co., 1622 Candler Bldg., Atlanta, Ga.

PRESSINGER, W. P. (Associate, 1903), W. P. Pressinger Co., 1 W. 34th St., New York, N. Y.

RATTLE, Paul S. (Junior, 1908), Sales Engr., The B. M. Osbun Co., 832 Commercial Natl. Bank Bldg., Chicago, Ill.

RIDDLE, Howard Sterling (1905), Wks. Mgr., Jeffrey Mfg. Co., Cote and Laganchiterre Sts., Montreal, Canada.

ROGERS, Robert W. (Junior, 1908), Pioneer Pub. Co., 1 Madison Ave., New York, N. Y.

SCHNUCK, Edward F. (1897; 1901), Production Engr., Director Jabez Burns & Sons, 600 W. 43d St., New York, N. Y.

SERGEANT, Chas. H. (1895), 611 W. 138th St., New York, N. Y.

STANTON, Frank McMillan (1892), Life Member, Room 409, 225 Fifth Ave., New York, N. Y.

STEVENS, Robt. H. (Junior, 1903), N. Y. Rep., Bethlehem Fdy. and Mch. Co., 149 Broadway, New York, and *for mail*, 780 E. 14th St., Flatbush, Brooklyn, N. Y.

STEVENS, Wm. N. (Junior, 1886), V. P., Conveying Mchy. Co., 120 Liberty St., New York, N. Y.

STOTT, Henry G. (1902), Mgr. 1907–1910; Supt. M. P., Interborough Rapid Transit Co., 600 W. 59th St., New York, and Rochelle Heights, New Rochelle, N. Y.

WARRINGTON, James N. (1884; 1885), 617 S. Grand Ave., Los Angeles, Cal.

WRAITH, William (1903), Supt., Washoe Smelter, P. O. Box 93, and 619 Main St., Anaconda, Mont.

NEW MEMBERS

JOHNSON, Louis L. (1908), The Westinghouse Mch. Co., Room 1412, N. Y. Life Bldg., Chicago, Ill.

MACLAREN, James G. (Associate, 1908), Engr., Lamson Cons. Store Service Co., Boston, and *for mail*, 109 Walter St., Roslindale, Mass.

SALTZMAN, Auguste L. (1908), Mech. Engr. and Supt., Cornwall, Plock & Saltzman, New York, N. Y., and *for mail*, 157 Central Ave., East Orange, N. J.

DEATHS

HILDRETH, Charles L.

RAND, Jasper R.

GAS POWER SECTION

CHANGES OF ADDRESS

BAEHR, William Alfred (1908), 1943 Commercial Natl. Bank Bldg., Chicago, Ill.

GREENE, Harris Ray (1908), Sales Engr., Alberger Condenser Co., 95 Liberty St., New York, N. Y., and 1406 Chapel St., New Haven, Conn.

LOZIER, Robert T. (Affiliate, 1908), Engineers' Club, 32 W. 40th St., New York, N. Y.

SERGEANT, Chas. H. (1908), 611 W. 138th St., New York, N. Y.

NEW MEMBERS

DANKS, Alfred C. (1909), Ch. Eng. of Gas Engines, Edgar Thomson Wks., Carnegie Steel Co., Braddock, and *for mail*, 331 West St., Wilkinsburg Sta., Pittsburg, Pa.

FISCHER, Wm. Francis (Affiliate, 1909), Engrg. Dept., N. Y. Edison Co., 55 Duane St., New York, N. Y.

HAYES, Frank A. (Affiliate, 1909), 409 Hartley Hall, Columbia Univ., New York, N. Y.

JACOB, Fred, Jr. (Affiliate, 1909), Estimating Engr., The Fairbanks Co., Broome and Lafayette Sts., New York, N. Y., and *for mail*, 110 Ridgewood Ave., Newark, N. J.

McNEIL, Merritt Chas. (Affiliate, 1909), Sales, R. D. Wood & Co., and *for mail*, 4834 Walton Ave., Philadelphia, Pa.

MYERS, Theodore B. (Affiliate, 1909), Gas Eng. Salesman, Otto Gas Eng. Wks., 138 Liberty St., New York, N. Y.

PRIDE, George H. (Affiliate, 1908), 277 Broadway, New York, N. Y.

RALSTON, Louis C. (Affiliate ,1909), 2613 Channing Way, Berkeley, Cal.

SEAGER, Schuyler F. (Affiliate, 1909). Secy. and Treas., Olds Gas Power Co., Lansing, Mich.

SUTER, John (Affiliate, 1909), care of F. P. Thorp, Internatl. Steam Pump Co., 115 Broadway, New York, N. Y.

WILE, Julius I. (1909), Sales Mgr., Producer Dept., Gas Mchy. Co., 56 Pine St., New York, N. Y.

WOLFE, Henry Geo. (Affiliate, 1909), Draftsman, N. Y. Edison Co., 55 Duane St., New York, and *for mail*, 65 Berkeley Pl., Brooklyn, N. Y.

COMING MEETINGS

Secretaries or members of societies whose meetings are of interest to engineers are invited to send in their notices for publication in this department. Such notices must be in the editor's hands by the 15th of the month preceding the meeting.

AERONAUTIC SOCIETY

May 12, etc., evenings, weekly meetings, Automobile Club of America, W. 54th St., New York. Secy., Wilbur R. Kimball.

AIR BRAKE ASSOCIATION

May 11–14, Annual Convention, Richmond, Va. Secy., F. M. Nellis, 53 State St., Boston, Mass.

AMERICAN ASSOCIATION OF DEMURRAGE OFFICERS

May 11, Southern Hotel, St. Louis, Mo., 10 a.m.

AMERICAN ASSOCIATION OF ELECTRIC MOTOR MANUFACTURERS

May 17–20, annual meeting, Hot Springs, Va.

AMERICAN CHEMICAL SOCIETY

May 14, New York section. Paper: Soluble and Fusible Condensation Products of Formaldehyde and Phenols, Dr. Baekeland. Secy., C. M. Joyce, Box 23, Arlington, N. J.

AMERICAN ELECTROCHEMICAL SOCIETY

May 5–8, annual meeting, Niagara Falls, Ont. Secy., Dr. J. W. Richards, Lehigh University, So. Bethlehem, Pa.

AMERICAN FOUNDRYMEN'S ASSOCIATION

May 18–20, Hotel Sinton, Cincinnati, O. Secy., Richard Moldenke, Watchung, N. J.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

June 24–25, semi-annual meeting, Brooklyn, N. Y. Secy., J. C. Olsen, Polytechnic Institute.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

May 18, monthly meeting, 33 W. 39th St., New York, 8 p. m. Paper: Patents, F. P. Fish. June 28, annual Convention, Frontenac, N. Y. Secy., R. W. Pope, 95 Liberty St. N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

May 21, monthly meeting, Toronto section. Secy. *pro tem*, W. H. Eisenheis, 1207 Traders' Bank Bldg.

AMERICAN RAILWAY ASSOCIATION

May 19, annual meeting, New York. Secy., W. F. Allen, 24 Park Pl.

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION

June 16–18, Annual Convention, Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

AMERICAN SOCIETY OF CIVIL ENGINEERS

May 19, June 2, semi-monthly meetings, 220 W. 57th St., New York. Secy., C. W. Hunt.

AMERICAN SOCIETY OF HUNGARIAN ENGINEERS AND ARCHITECTS
June 5, 29 W. 39th St., New York, 8.30 p.m. Secy., Zoltan de Németh, 103 E. 16th St.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS
May 4–7, Spring Meeting, Washington, D. C. Secy., C. W. Rice, 29 W. 39th St., New York.

AMERICAN SOCIETY OF SWEDISH ENGINEERS
May 1, May 15, semi-monthly meetings, Brooklyn, N. Y. Papers: May 1, The Austin Rotary Engine, Wm. K. Austin; May 15, Steam and its Behavior in Turbines, Ernst J. Berg. Secy., E. Hammerstrom, 271 Hicks St.

AMERICAN WATER WORKS ASSOCIATION
June 8–12, annual Convention, Milwaukee, Wis. Secy., J. M. Diven, 14 George St., Charleston, S. C.

ARKANSAS ASSOCIATION OF PUBLIC UTILITY OPERATORS
May 12–14, Hot Springs. Secy., J. E. Cowles, Little Rock.

ASSOCIATION OF CAR LIGHTING ENGINEERS
June 7, semi-annual meeting, New York. Secy., G. B. Colgrove, I. C. R. R., Chicago, Ill.

ASSOCIATION OF RAILWAY CLUB SECRETARIES
June 19, annual meeting, Atlantic City, N. J.

ASSOCIATION OF RAILWAY TELEGRAPH SUPERINTENDENTS
June 23–25, Detroit, Mich. Secy., P. W. Drew, Room 511, Harvester Bldg., Chicago, Ill.

BLUE ROOM ENGINEERING SOCIETY
June 3, monthly meeting, 29 W. 39th St., New York, 8 p.m. Secy., W. D. Sprague.

BOSTON SOCIETY OF CIVIL ENGINEERS
May 19, monthly meeting, Tremont Temple. Secy., S. E. Tinkham, 60 City Hall.

BROOKLYN ENGINEERS' CLUB
May 6, 117 Remsen St. Paper: The Oxy-Acetylene Welding Process. Henry R. Cobleigh. Secy., Joseph Strachan.

CANADIAN ELECTRICAL ASSOCIATION
June 16–18, annual Convention, Quebec. Secy., T. S. Young, Confederation Life Bldg., Toronto.

CANADIAN GAS ASSOCIATION
June 25, annual meeting, Toronto, Ont. Secy. A. W. Moore, Woodstock.

CANADIAN SOCIETY OF CIVIL ENGINEERS, Toronto Branch, May 27, regular meeting, 96 King St., W. Secy., T. C. Irving, Jr.

CAR FOREMEN'S ASSOCIATION OF CHICAGO
May 10, monthly meeting, Masonic Temple. Secy., Aaron Kline, 326 N. 50th St.

CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA
May 18, monthly meeting, Rossin House, Toronto, Ont. Secy., C. L. Worth, Room 409, Union Sta.

CENTRAL RAILWAY CLUB
May 14, monthly meeting, Hotel Iroquois, Buffalo, N. Y., 8 p.m. Secy., H. D. Vought, 95 Liberty St., New York.

CHICAGO ELECTRIC CLUB

May 12, etc., weekly meetings, noon, Chicago Automobile Club. Secy., W. S. Taussig, 204 Dearborn St.

CIVIL ENGINEERS' CLUB OF CLEVELAND

May 11, June 8, monthly meetings, 714–719 Caxton Bldg., Secy., J. C. Beardley.

CIVIL ENGINEERS' CLUB OF ST. PAUL

May 10, June 7, monthly meetings. Secy , G. E. Edmonstone.

CLEVELAND ENGINEERING SOCIETY

May 11, monthly meeting, Caxton Bldg. Secy., Joe C. Beardsley.

COLORADO SCIENTIFIC SOCIETY

June 5, monthly meeting, Denver. Secy., Dr. W. A. Johnston, 801 Symes Bldg.

DENVER SOCIETY OF CIVIL ENGINEERS

May 11, June 8, monthly meetings, 36 Jacobson Bldg. Secy., Walter Pearl.

EASTERN RAILROAD ASSOCIATION

May 13, annual meeting. Secy., John J. Harrower, 614 F St. N. W., Washington, D. C.

ENGINEERING ASSOCIATION OF THE SOUTH

May 18, monthly meeting. Secy., H. M. Jones, 2 Berry Blk., Nashville, Tenn.

ENGINEERING SOCIETY OF THE STATE UNIVERSITY OF IOWA

June 1, monthly meeting, Iowa City. Secy., Dean Wm. G. Raymond.

ENGINEERS AND ARCHITECTS' CLUB OF LOUISVILLE, KY.

May 17, monthly meeting, 303 Norton Bldg. Secy., Pierce Butler.

ENGINEERS' CLUB OF BALTIMORE

June 5, annual meeting. Secy., R. K. Compton, City Hall.

ENGINEERS' CLUB OF CENTRAL PENNSYLVANIA

June 1, annual meeting, Gilbert Bldg., Harrisburg. Secy., E. R. Dasher.

ENGINEERS' CLUB OF CHICAGO

May 18, June 1, semi-monthly meetings, Jefferson Hall, 70 Adams St. Secy., D. W. Thurtell, 1223 New York Life Bldg.

ENGINEERS' CLUB OF CINCINNATI

May 20, monthly meeting, 25 E. 8th St. Secy., E. A. Gast, P. O. Box 333.

ENGINEERS' CLUB OF MINNEAPOLIS

May 17, monthly meeting, City Hall.

ENGINEERS' CLUB OF PHILADELPHIA

May 15, June 5, semi-monthly meetings, 1122 Girard St. Secy., W. L. Webb.

ENGINEERS' CLUB OF ST. LOUIS

May 19, June 2, semi-monthly meetings, 3817 Olive St. Secy., R. H. Fernald.

ENGINEERS' CLUB OF TORONTO

May 13, etc., weekly meetings, 96 King St., W. Secy., R. B. Woolsey.

ENGINEERS' SOCIETY OF MILWAUKEE

May 12, monthly meeting, 456 Broadway. Secy., W. Fay Martin.

ENGINEERS' SOCIETY OF WESTERN PENNSYLVANIA

May 18, regular meeting; May 20, Chemical section; May 25, Structural section; June 1, Mechanical section; 803 Fulton Bldg., Pittsburgh. Secy., Edmund Yardley.

EXPLORERS' CLUB

June 4, 29 W. 39th St., New York, 8.30 p.m. Secy., H. C. Walsh.

FREIGHT CLAIM ASSOCIATION

June 16, annual meeting, Old Point Comfort, Va. Secy., W. P. Taylor, Richmond, Va.

FOUNDRY AND MANUFACTURERS' SUPPLY ASSOCIATION

May 17–22, annual meeting and exhibit, Cincinnati, O. Secy., C. E. Hoyt, Lewis Institute, Chicago, Ill.

GENERAL MANAGER'S ASSOCIATION OF CHICAGO

May 20, monthly meeting. Secy., H. Deeming.

GENERAL SUPERINTENDENTS' ASSOCIATION OF CHICAGO

May 19, Chicago. Secy., H. D. Judson, C. B. & Q. R. R.

ILLUMINATING ENGINEERING SOCIETY

May 13, monthly meeting, New York section, 29 W. 39th St., 8 p.m. Secy., P. S. Millar.

INTERNATIONAL RAILWAY FUEL ASSOCIATION

June 21–23, annual meeting, Auditorium Hotel, Chicago, Ill. Secy., D. B. Sebastian, 327 La Salle St. Sta., Chicago.

INTERNATIONAL RAILWAY GENERAL FOREMEN'S ASSOCIATION

June 1–5, annual meeting, Chicago, Ill. Secy., E. C. Cook, Royal Insurance Bldg.

IOWA DISTRICT GAS ASSOCIATION

June 23–25, annual meeting, Waterloo, Ia. Secy., G. I. Vincent, Des Moines.

IOWA RAILWAY CLUB

May 14, monthly meeting, Des Moines. Secy., W. B. Harrison, Union Sta.

LOUISIANA ENGINEERING SOCIETY

May 10, monthly meeting, 323 Hibernia Bldg., New Orleans. Secy., L. C. Datz.

MASSACHUSETTS STREET RAILWAY ASSOCIATION

May 13, June 9, monthly meetings, Boston. Secy., Chas. S. Clark, 70 Kilby St.

MASTER CAR BUILDERS' ASSOCIATION

June 21–23, annual Convention, Atlantic City, N. J. Secy., Jos. W. Taylor, 390 Old Colony Bldg., Chicago, Ill.

MASTER MECHANICS ASSOCIATION

June Convention, Atlantic City, N. J.

MODERN SCIENCE CLUB

May 4, weekly meeting, 125 S. Elliott Pl., Brooklyn, N. Y. Paper: Autogenous Welding with Oxy-Acetylen, E. Bournvonville. May 8, Papers: House-Heating Boilers, May 22, Papers: Turbine Governors. May 25, Papers: Elevator Accidents and their Prevention, F. E. Town. Secy., Jas. A. Donnelly.

MUNICIPAL ENGINEERS OF THE CITY OF NEW YORK

May 26, 29 W. 39th St., 8.15 p.m. Secy., C. D. Pollock.

NATIONAL ASSOCIATION OF AUTOMOBILE MANUFACTURERS

June 2, monthly meeting, New York. Secy., C. C. Hildebrand, 7 E. 42d St.

NATIONAL ASSOCIATION OF MANUFACTURERS
May 17–19, Convention, Waldorf-Astoria, New York. Secy., Geo. S. Boudinot, 170 Broadway.

NATIONAL ELECTRIC LIGHT ASSOCIATION
June 1–4, Atlantic City, N. J. Secy., John F. Gilchrist, 29 W. 39th St., New York.

NATIONAL FIRE PROTECTION ASSOCIATION
May 25–27, annual meeting, 32 Nassau St., New York. Papers: Recent efforts to create the office of State Fire Marshal, Clarence Maris; Concrete Building Construction, Leonard C. Wason, The New York High-Pressure System. Alfred G. Patton, Secy., W. H. Merrill, 382 Ohio St., Chicago, Ill.

NATIONAL GAS AND GASOLENE ENGINE TRADES ASSOCIATION
June 22–24, Oliver Hotel, South Bend, Ind. Secy., A. Stritmatter, Cincinnati, Ohio.

NATURAL GAS ASSOCIATION OF AMERICA
May 18–21, Annual Convention, Goodale St. Auditorium, Columbus, O. Secy., L. S. Bigelow, 265 Broadway, New York.

NEW ENGLAND RAILROAD CLUB
May 11, monthly meeting, Copley Square Hotel, Boston, Mass., 8 p.m. Secy., Geo. H. Frazier, 10 Olive St.

NEW ENGLAND STREET RAILWAY CLUB
May 27, monthly meeting, American House, Boston, Mass. Secy., John J. Lane, 12 Pearl St.

NEW YORK RAILROAD CLUB
May 21, monthly meeting, 29 W. 39th St., 8.15 p.m. Secy., H. D. Vought, 95 Liberty St.

NEW YORK SOCIETY OF ACCOUNTANTS AND BOOKKEEPERS
May 11, etc., weekly meetings, 29 W. 39th St., 8 p.m. Secy., T. L. Woolhouse.

NEW YORK TELEPHONE SOCIETY
May 18, monthly meeting, 29 W. 39th St., 8 p.m. Secy. T. H. Laurence.

NORTHERN RAILWAY CLUB
May 22, monthly meeting, Commercial Club Rooms, Duluth, Minn. Secy., C. L. Kennedy.

NORTHWEST RAILWAY CLUB
May 11, monthly meeting, St. Paul, Minn. Secy., T. W. Flannagan, care Soo Line.

NOVA SCOTIA SOCIETY OF ENGINEERS
May 13, monthly meeting, Halifax. Secy., S. Fenn.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS
May 21, 22, spring meeting, Canton. Secy., David Gaehr, Schofield Bldg., Cleveland.

OPTOMETRICAL SOCIETY OF THE CITY OF NEW YORK
May 12, June 9, monthly meetings, 29 W. 39th St., 8 p.m. Secy., J. H. Drakeford.

PACIFIC COAST RAILWAY CLUB
May 15, monthly meeting, San Francisco, Cal. Secy., E. C. Borton, West Oakland, Cal.

PROVIDENCE ASSOCIATION OF MECHANICAL ENGINEERS
May 25, monthly meeting, Technical High School Hall, 8 p.m. June 22, annual meeting. Secy., T. M. Phetteplace.

PURDUE MECHANICAL ENGINEERING SOCIETY
May 12, etc., fortnightly meetings, Purdue University, Lafayette, Ind., 6.30 p.m. Secy., L. B. Miller.

RAILWAY CLUB OF KANSAS CITY
May 21, 904 Delaware St. Secy., Claude Manlove.

RAILWAY CLUB OF PITTSBURGH
May 28, monthly meeting, Monongahela House, 8 p.m. Secy., J. D. Conway, Genl. Office, P. & L. E. R. R.

RAILWAY SIGNAL ASSOCIATION
June 8, 29 W. 39th St., New York, 10 a.m. Secy., C. C. Rosenberg, 712 North Linden St., Bethlehem, Pa.

RAILWAY STOREKEEPERS' ASSOCIATION
May 17–19, annual meeting, Chicago, Ill. Secy., J. P. Murphy, L. S. & M. S. Ry., Collingwood, O.

RENSSELAER SOCIETY OF ENGINEERS
May 21, etc., fortnightly meetings, 257 Broadway, Troy, N. Y. Secy., R. S. Furber.

ROCHESTER ENGINEERING SOCIETY
May 14, monthly meeting. Secy., John F. Skinner, 54 City Hall.

ROCKY MOUNTAIN RAILWAY CLUB
May 15, monthly meeting. Secy., J. E. Buell, Denver, Colo.

ST. LOUIS RAILWAY CLUB
May 14, monthly meeting, Southern Hotel, 8 p.m. Secy., B. W. Frauenthal, Union Sta.

SCRANTON ENGINEERS' CLUB
May 20, monthly meeting, Board of Trade Bldg. Secy., A. B. Dunning.

SHORT LINE RAILROAD ASSOCIATION
June 7, New York. Secy., John N. Drake, 60 Wall St.

SOUTHWESTERN ELECTRICAL AND GAS ASSOCIATION
May, Annual Convention, Dallas, Texas.

TECHNICAL SOCIETY OF BROOKLYN
May 15, June 4, semi-monthly meetings. Arion Hall, Arion Pl., 8.30 p.m. Pres., M. C. Budell, 20 Nassau St., New York.

TECHNOLOGY CLUB OF SYRACUSE
May 12, monthly meeting, 502 Bastable Blk., 8 p.m. Secy., Robert L. Allen.

TECHNICAL SOCIETY OF THE PACIFIC COAST
June 4, San Francisco, Cal. Secy., Otto von Geldern, 1978 Broadway.

TRAIN DESPATCHERS' ASSOCIATION OF AMERICA
June 15, annual Convention, Columbus, O. Secy., J. F. Mackie, La Salle St. Sta., Chicago, Ill.

WESTERN RAILWAY CLUB
May 18, monthly meeting, Auditorium Hotel, Chicago, Ill., 8 p.m. Secy., Joseph W. Taylor, 390 Old Colony Bldg.

WESTERN SOCIETY OF ENGINEERS
May 19, etc., fortnightly meetings, May 12, Electrical section, Chicago, Ill. Secy., J. H. Warder, 1737 Monadnock Blk.

WIRELESS INSTITUTE

June 2, 29 W. 39th St., New York. Secy., S. L. Williams.

WISCONSIN GAS ASSOCIATION

May 12, 13, annual Convention, Milwaukee. Secy., Henry H. Hyde, Racine.

MEETINGS TO BE HELD IN ENGINEERING SOCIETIES' BUILDING

Date	Society	Secretary	Time
May			
11	N. Y. Society Accountants and Bkprs.	T. L. Woolhouse	8:00
12	Optometrical Society of the City of N. Y.	J. H. Drakeford	8:00
13	Illuminating Engineering Society	P. S. Millar	8:00
18	N. Y. Society Accountants and Bkprs.	T. L. Woolhouse	8:00
18	New York Telephone Society	T. H. Laurence	8:00
18	American Institute Electrical Engineers	R. W. Pope	8:00
19	American Railway Association	W. F. Allen	All day
21	New York Railroad Club	H. D. Vought	8:15
25	N. Y. Society Accountants and Bkprs.	T. L. Woolhouse	8:00
26	Municipal Engineers of City of New York	C. D. Pollock	8:15
June			
1	N. Y. Society Accountants and Bkprs.	T. L. Woolhouse	8:00
2	Wireless Institute	S. L. Williams	7:30
3	Blue Room Engineering Society	W. D. Sprague	8:00
4	Explorers' Club	H. C. Walsh	8:30
5	Amer. Soc. Hungarian Engrs. and Archts.	Z. de Németh	8:30
8	N. Y. Society Accountants and Bkprs.	T. L. Woolhouse	8:00
8	Railway Signal Association	C. C. Rosenberg	1:00 a. m.
9	Optometrical Society of City of N. Y.	J. H. Drakeford	8:00

OFFICERS AND COUNCIL

PRESIDENT

Jesse M. Smith .... **New York**

VICE-PRESIDENTS

L. P. Breckenridge .... Urbana, Ill.
Fred J. Miller .... Center Bridge, Pa.
Arthur West .... E. Pittsburg, Pa.

Terms expire at Annual Meeting of 1909

Geo. M. Bond .... **Hartford, Conn.**
R. C. Carpenter .... **Ithaca, N. Y.**
F. M. Whyte .... **New York**

Terms expire at Annual Meeting of 1910

PAST PRESIDENTS

Members of the Council for 1909

Ambrose Swasey .... Cleveland, O.
John R. Freeman .... Providence, R. I.
Frederick W. Taylor .... Philadelphia, Pa.
F. R. Hutton .... New York
M. L. Holman .... **St. Louis, Mo.**

MANAGERS

G. M. Basford .... New York
A. J. Caldwell .... Newburg, N. Y.
A. L. Riker .... Bridgeport, Conn.

Terms expire at Annual Meeting of 1909

Wm. L. Abbott .... **Chicago, Ill.**
Alex. C. Humphreys .... New York
Henry G. Stott .... New Rochelle, N. Y.

Terms expire at Annual Meeting of 1910

H. L. Gantt .... **Pawtucket, R. I.**
I. E. Moultrop .... **Boston, Mass.**
W. J. Sando .... **Milwaukee, Wis.**

Terms expire at Annual Meeting of 1911

TREASURER

William H. Wiley .... New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt .... New York

HONORARY SECRETARY

F. R. Hutton .... New York

SECRETARY

Calvin W. Rice .... 29 W. 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Jesse M. Smith, *Chairman*
Alex. C. Humphreys
F. R. Hutton
Fred J. Miller
Frederic M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (1), *Chairman*
Edward F. Schnuck (2)
Geo. J. Roberts (3)
Robert M. Dixon (4)
Waldo H. Marshall (5)

MEETINGS

Willis E. Hall (1), *Chairman*
Wm. H. Bryan (2)
L. R. Pomeroy (3)
Charles E. Lucke (4)
H. de B. Parsons (5)

PUBLICATION

Arthur L. Williston (1), *Chairman*
D. S. Jacobus (2)
H. F. J. Porter (3)
H. W. Spangler (4)
Geo. I. Rockwood (5)

MEMBERSHIP

Henry D. Hibbard (1), *Chairman*
Charles R. Richards (2)
Francis H. Stillman (3)
George J. Foran (4)
Hosea Webster (5)

LIBRARY

John W. Lieb, Jr. (4), *Chairman*
H. H. Suplee (1)
Ambrose Swasey (2)
Leonard Waldo (3)
Chas. L. Clarke (5)

HOUSE

Henry S. Loud (1), *Chairman*
William Carter Dickerman (2)
Bernard Victor Swenson (3)
Francis Blossom (4)
Edward Van Winkle (5)

RESEARCH

Jas. Christie (1)
R. C. Carpenter (2)
R. H. Rice (3)
Chas. B. Dudley (4)
W. F. M. Goss (5)

Note.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

SPECIAL COMMITTEES

1909

On a Standard Tonnage Basis for Refrigeration

D. S. Jacobus
G. T. Voorhees
A. P. Trautwein
Philip De C. Ball
E. F. Miller

On Society History

John E. Sweet
H. H. Suplee
Charles Wallace Hunt

On Constitution and By-Laws

Chas. Wallace Hunt, *Chairman*
F. R. Hutton
G. M. Basford
D. S. Jacobus
Jesse M. Smith

On Conservation of Natural Resources

Geo. F. Swain, *Chairman*
L. D. Burlingame
Charles Whiting Baker
M. L. Holman
Calvin W. Rice

On International Standard for Pipe Threads

E. M. Herr, *Chairman*
Geo. M. Bond
William J. Baldwin
Stanley G. Flagg, Jr.

On Thurston Memorial

Alex. C. Humphreys, *Chairman*
Charles Wallace Hunt
R. C. Carpenter
J. W. Lieb, Jr.
Fred J. Miller

On Hudson-Fulton Celebration

Geo. W. Melville
M. L. Holman
Jesse M. Smith

On Standards for Involute Gears

Hugo Bilgram
Gaetano Lanza
C. R. Gabriel
Wilfred Lewis
Chas. W. McCord

SOCIETY REPRESENTATIVES
1909

On John Fritz Medal

HENRY R. TOWNE (1)
AMBROSE SWASEY (2)
F. R. HUTTON (3)
CHARLES WALLACE HUNT (4)

On Board of Trustees United Engineering Societies Building

CHAS. WALLACE HUNT (1)
F. R. HUTTON (2)
FRED J. MILLER (3)

On Joint Library Committee

THE CHAIRMAN OF THE LIBRARY COMMITTEE OF THE AM. SOC. M. E.

On National Fire Protection Association

JOHN R. FREEMAN
IRA H. WOOLSON

On Joint Committee on Engineering Education

ALEX. C. HUMPHREYS
F. W. TAYLOR

On Government Advisory Board on Fuels and Structural Materials

GEO. H. BARRUS
P. W. GATES
W. F. M. GOSS

On Advisory Board National Conservation Commission

GEO. F. SWAIN
JOHN R. FREEMAN
CHAS. T. MAIN

On Council of American Association for the Advancement of Science

ALEX. C. HUMPHREYS
FRED J. MILLER

NOTE.—Numbers in parentheses indicate length of term in years that the member has yet to serve.

OFFICERS OF THE GAS POWER SECTION

1909

CHAIRMAN

F. R. Low

SECRETARY

Geo. A. Orrok

GAS POWER EXECUTIVE COMMITTEE

F. H. Stillman, *Chairman*
F. R. Hutton
G. I. Rockwood
H. H. Suplee
R. H. Fernald

GAS POWER MEMBERSHIP COMMITTEE

Robert T. Lozier, *Chairman*
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H. V. O. Coes
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F. S. King
D. B. Rushmore
A. F. Stillman
G. M. S. Tait
George W. Whyte
S. S. Wyer

GAS POWER MEETINGS COMMITTEE

Cecil P. Poole, *Chairman*
R. T. Kent
E. S. McClelland
C. W. Obert
C. T. Wilkinson

GAS POWER LITERATURE COMMITTEE

C. H. Benjamin, *Chairman*
H. R. Cobleigh
G. D. Conlee
R. S. deMitkiewicz
H. T. Eddy
L. V. Goebbels
L. N. Ludy
L. S. Marks
T. M. Phetteplace
G. J. Rathbun
W. Rautenstrauch
S. A. Reeve
A. J. Wood

GAS POWER INSTALLATIONS COMMITTEE

J. R. Bibbins, *Chairman*
A. Bement
L. B. Lent

GAS POWER PLANT OPERATIONS COMMITTEE

I. E. Moultrop, *Chairman*
W. H. Blauvelt
V. Z. Caracristi
E. P. Coleman
C. J. Davidson
W. T. Donnelly
H. J. K. Freyn
N. T. Harrington
J. B. Klumpp
G. L. Knight
J. L. Lyon
D. T. McLeod
V. E. McMullen
C. H. Parker
J. P. Sparrow
A. B. Steen
F. W. Walker
C. W. Whiting
Paul Winsor
T. H. Yawger

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